THE REPUBLIC OF RWANDA

Ministry of Natural Resources

Rwanda Natural Resources Authority (RNRA)

Department of Forestry and Nature Conservation (DFNC)

Final report

Update and upgrade of WISDOM Rwanda and Woodfuels value chain analysis As a basis for the

Rwanda Supply Master Plan for fuelwood and charcoal

Prepared by

Rudi Drigo, Anicet Munyehirwe, Vital Nzabanita and Athanase Munyampundu

AGRICONSULTING S.p.A.

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Project

"Rwanda Supply Master Plan for Firewood and Charcoal"

Support Program to the Development of the Forestry Sector (PAREF-B2)

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ACRONYMS AND DEFINITIONS

Acronyms

ad	Air dry (biomass, usually measured in kg or t, with approx. 12% moisture content)
AME	"ameliorated" woodfuel demand scenario assuming (i) a 30% increase in the penetration of improved stoves, (ii) a higher efficiency in charcoal production from 12 to 18%, and (iii) a higher penetration of LPG in urban areas.
BAU	Business as usual. Used to indicate current conditions in demand and supply scenarios.
BEST	Biomass Energy Strategy. Programme implemented by the Ministry of Infrastructure with support from GTZ (GIZ), Germany
C GIS NUR	Centre d'Information Géographique et de Télédétection de l'Université Nationale du Rwanda
CFSVA	Comprehensive Food Security and Vulnerability Analysis and Nutrition Survey (WFP and NISR, 2009)
DFNC	Department of Forestry and Nature Conservation (DFNC) in RNRA
EICV	Integrated Household Survey on Living Conditions (Enquête Intégrale sur les Conditions de Vie des Ménages). Surveys carried out by the National Institute of Statistics of Rwanda: EICV 1 (2000-2001) EICV 2 (2005-2006); EICV 3 (2010-2011).
ESSP	Energy Sector Strategic Plan
EWSA	Energy, Water and Sanitation Authority
FAO	Food and Agriculture Organization of United Nations
FGDs	Focus Group Discussions
GIS	Geographic Information System
HH	Household (abbreviation used in tables)
ISAR	Institut des Sciences Agronomiques du Rwanda
KWSMP	Kigali Woodfuels Supply Master Plan
MAI	Mean Annual Increment
MAN	"managed" productivity variant assuming an increased annual productivity for eucalyptus plantations to 15 m^3 ha^{-1} $year^{-1}$ (from the current 9.6 m^3) as result of appropriate management
MINAGRI	Ministry of Agriculture and Animal Resources.
MINALOC	Ministry of Local Government
MININFRA	Ministry of Infrastructure
MINIRENA	Ministry of Natural Resources (establ. March 2008)
MINITERE	Ministère des Terres, de l'Environnement, des Forêts, de l'Eau et des Ressources Naturelles (now MINIRENA)
MINITRAPE	Ministère des Travaux Publics, de l'Energie et de l'Eau (now MININFRA)
NAFA	National Forestry Authority (under MINIRENA), now Department of Forestry and Natural Conservation (DFNC) in RNRA
NISR	Institut National de Statistiques, Rwanda
od	Oven dry (biomass, usually measured in kg or t, with 0% moisture content)
PAREF	Programme d'Appui à la Reforestation (MINIRENA Programme)
PAREF.be2	Support Program to the Development of the Forestry Sector in Rwanda (component of PAREF funded by Belgium)
PAREF.Nl	Support Program to the Reforestation in Rwanda (component of PAREF funded by the Netherlands)
RBESS 2009	Rwanda Biomass Energy & Stoves Survey 2009, MININFRA, Carried out By Green & Clean
RDB/ICT	Rwanda Development Board/ Information, communication and Technology Department

RDHS 2010	2010 Rwanda Demographic and Health Survey. The survey was implemented by the National Institute of Statistics of Rwanda (NISR) and the Ministry of Health (MOH).
REMA	Rwanda Environment Management Authority
RITA	Rwanda Information and Technology Agency (under MININFRA)
RNRA	Rwandan Natural Resources Authority
RRA	Rwanda Revenue Authority
SEW/IFDC	Sustainable Energy Production through Woodlots and Agroforestry in the Albertine Rift. Regional Project implemented by the International Fertilizer Development Centre (IFDC).
Stere	Cubic Meter as measured in stacks
TOF	Trees Outside Forest (survey)
WISDOM	Woodfuel Integrated Supply/Demand Overview Mapping (methodology)
kt	Kilo ('000) metric tons; thousand tons.
kt od	Thousand metric tons oven dry (Dry Matter)
t	Metric ton ('000 kg)
w.eq.	Wood equivalent. In case of charcoal, it refers to the quantity of wood needed for the production of a certain quantity of charcoal.

Selected definitions

The terms and concepts used in this paper make reference to the definitions and terminology provided in the FAO document "Unified Bioenergy Terminology" (UBET), FAO 2004.

Fuelwood	woodfuel where the original composition of the wood is preserved (charcoal and black liquor are excluded)
Charcoal	solid residue derived from carbonization distillation, pyrolysis and torrefaction of fuelwood
Woodfuels	all types of biofuels originating directly or indirectly from woody biomass. (Includes fuelwood, charcoal and black liquor)
Wood energy	energy derived from woodfuels corresponding to the net calorific value of the fuel
Wood energy systems	all the (steps and/or) unit processes and operations involved for the production, preparation, transportation, marketing, trade and conversion of woodfuels into energy

EXECUTIVE SUMMARY – DOCUMENT DE SYNTESE

Executive Summary

Rwanda is a small country with a large population that depends on woody biomass as primary source of energy. The wood resources are limited and the demand for woodfuels is high, and increasing, as it is clear that in the short and medium term woodfuels will remain the only affordable fuel for the majority of Rwandese population. Kigali plays a dominant role in the national wood energy context, with a demand for charcoal that covers some 60% of the entire national requirement for such commodity. There is also no doubt that this great demand for fuelwood and charcoal, embodied by the constant flow of charcoal into Kigali, exerts a considerable pressure on the wood resources of the country, giving rise to serious and widespread concern about the sustainability of supply.

Securing essential energy levels and at the same time protecting the environment and the productive capacity of forest plantations, natural vegetations and farmlands represents a major planning challenge and the Ministry of Natural Resources, in the framework of Vision 2020 and of the National Forestry Policy, decided to launch the elaboration of the Masterplan for the Supply of Charcoal and Fuelwood of Kigali.

This study was carried out in the framework of the Support Program to the Development of the Forestry Sector (PAREF.be2), supported by Belgium/Rwanda (2012-2015), under authority of the Rwanda Natural Resources Authority (RNRA), Department of Forestry and Nature Conservation (DFNC). Technical assistance was provided by Agriconsulting S.p.A.

In order to support the formulation of sound operational strategies, key questions to be answered were:

- What is the consumption of fuelwood and charcoal?
- What is the sustainable production capacity?
- What is the current national supply/demand balance? And what is it likely to become by 2020?
- Where is the balances negative and where it is positive?
- What can be done between now and 2020 to achieve a sustainable balance? And where should it be done?

Given the certitude of a negative national supply/demand balance, it was immediately evident that the analysis for enabling the elaboration of a Master Plan could not be limited to Kigali town and its surrounding or supposed supply zones, but rather required a comprehensive country-wide diagnostic on the current and forthcoming woodfuels demand, on the sustainable supply potential and a thorough analysis of the socio-economic dimensions of the wood energy sector. In order to produce such nation-wide diagnostic, the WISDOM analysis[1] previously carried out by FAO/NAFA was updated and upgraded and a socio-economic analysis was carried out using existing information and new field data. The WISDOM analysis provides a comprehensive country-wide description of woodfuels' demand and supply in 2009 (year determined by the new C GIS NUR forest map) and probable 2020 scenarios. In consideration of the national scope of the analysis, the Validation Workshop held in Kigali on 17th July 2013 decided to change post-facto the title of the study by referring to the Supply Master Plan for Firewood and Charcoal of Rwanda, rather than Kigali.

KEY FINDINGS:

Baseline year 2009:

The 2009 consumption of fuelwood was 3.2 million tons (dry matter), 88% of which consumed by rural

[1] The methodology Woodfuels Integrated Supply/Demand Overview Mapping (WISDOM) is a diagnostic and planning tool in support to wood energy planning and policy formulation developed by FAO (Drigo et al. 2002; FAO 2003). WISDOM was implemented for Rwanda in 2009-2010 by FAO/NAFA (Drigo and Nzabanita, FAO 2011) with baseline year 2006.

See: http://www.fao.org/docrep/013/ma223e/ma223e00.pdf .

households, including in this value "conventional" fuelwood made by stemwood and branchwood as well as "marginal" fuelwood made by deadwood, twigs and pruning of farm trees used by rural households in wood-scarce areas. Although there is no reliable data on the quantity and distribution of "marginal" fuelwood use, the distinction between conventional and marginal fuelwood is quite important in the analysis of supply/demand balance, because the information about the supply potential is limited to "conventional" wood assortments.

In 2009 the consumption of charcoal was 226 thousand tons, equivalent, in terms of woody biomass, to 1.5 million tons (dry matter).

The total demand for woody biomass in 2009 was 4.8 million tons, including all types of fuelwood, charcoal and construction material. By excluding from this the probable fraction of "marginal" fuelwood, the total demand for conventional woody biomass in 2009 was approximately 4.2 million tons. The Kigali City Province, with 1.1 million tons, covered 26% of the national demand.

The sustainable supply potential in 2009 was approximately 3.2 million tons, according to the Medium Productivity variant (range 2.6 - 4.3, according to Low and High Productivity variants). This is significantly higher than previous estimates (BEST, FAO, based on ISAR 2007) with the increase due to information as provided by the new forest map based on high-resolution aerial photos (C GIS NUR 2012), which revealed a much greater plantation area that previously estimated (C GIS NUR 2007). To be noted that forest productivity data is scarce in Rwanda and that a nation-wide inventory of biomass sources specifically focused on their sustainable growth potential (as the one planned by PAREF) is urgent and absolutely essential.

The 2009 balance between the sustainable supply potential (Medium Productivity variant) and the consumption of "conventional" woody biomass presented a deficit of 870 thousand tons, or 21% of the demand for that year. This is a significant gap but it is not as dramatic as previously estimated[2]. This level of deficit may be responsible for overexploitation of existing resources and cause of degradation of natural forests and plantations. The only way to verify the rate of on-going degradation and deforestation processes will be to carry out a land cover monitoring study, which is strongly recommended.

2020 scenarios

Two demand scenarios were considered while projecting the situation to 2020:

- A "business-as-usual" (BAU) demand scenario, depicting the probable situation in 2020 if nothing special is done to change the current situation. This scenario assumes stable per capita consumption values and normal trends in the penetration of alternative fuels, such as LPG, as an effect of economic growth;
- An "ameliorated" (AME) demand scenario, assuming: (i) a 30 % increase in the penetration of improved stoves; (ii) a higher efficiency in charcoal production, and (iii) a higher penetration of LPG in urban areas.

According to the BAU scenario, the demand of woody biomass for energy and construction in 2020 will be 5.7 million tons (from the 4.2 of 2009). In this scenario the demand in Kigali City Province will cover 27 % of the national demand.

The efforts assumed in the AME scenario to reduce the demand and increase conversion efficiencies, will consider being able to maintain the growth of the demand due to population growth to a minimum but not be able to actually reduce it. The AME demand in 2020 is estimated to be 4.4 million tons. In this scenario the demand in Kigali City Province will be reduced to 0.85 million tons (from the 1.1 of 2009), covering only 19 % of the national demand.

Concerning the supply potential in 2020, a slight increase of planted areas is expected (here quantified at 10%), as effect of private planting trends and of the foreseen planting programs, such as PAREF. Plantation area in 2020 is expected to be over 315 thousand hectares and, assuming Medium Productivity,

[2] The first WISDOM analysis, based on the information available, estimated for year 2006 a national deficit of 1.8 million tons, or 61% of the demand (Drigo and Nzabanita, 2011, for FAO/NAFA).

the overall supply potential is expected to increase from 3.3 to 3.6 million tons (approximately 5.1 million m^3 of wood).

The 2020 balance according to the BAU Demand scenario and "normal" supply potential will show a deficit of 2.1 million tons. This gap represents 37% of the expected 2020 demand and the expected impact on the environment will be considerably greater than in 2009. While part of this gap may be filled in by marginal wood products and by a higher proportion of crop residues in the household energy mix, it is indubitable that the increased demand without a proportionate increase of the supply potential will induce further overexploitation of forest resources. In turn, the increased use of farm and crop residues for energy rather than leaving them in situ will have a negative impact on the soil nutrients cycle and farm productivity.

According to the AME Demand scenario and "normal" supply potential, the balance in 2020 will still show a national-level deficit of 820 thousand tons, which is quite close to that of 2009. This shows that operating only on the demand side by improving energy conversion efficiency (improved stoves), charring techniques and subsidizing LPG, cannot resolve the situation, but can merely offset the effect of population growth and maintain the level of supply/demand deficit relatively stable.

It is therefore essential to act with strong determination on increasing the supply as well, and the Country has a strong potential for this. For instance, if the productivity of the 2020 planted area could be increased from medium to high productivity level, the balance between such increased supply and the AME Demand scenario would be positive, with a surplus of approximately 108 thousand tons. In this respect, specific lines of interventions to be undertaken in the forestry and agro-forestry sectors aiming at increasing the supply, along with those oriented to the reduction of the demand, are discussed below in the context of a comprehensive wood energy strategy.

What is the woodfuels trade worth?

The value of the charcoal market of Rwanda in 2009 is estimated at 37.9 billion RWF, according to current market price, with 22.3 billion RWF in the urban area of Kigali only. More complex is to assess in monetary terms the economic magnitude of fuelwood trade due to the strong informal component and to the wide range of market prices. However, allocating a small price for the non-commercial fuelwood consumed by rural households and applying common commercial prices, the total value of fuelwood in 2009 may be quantified at 58.9 billion RWF. In total, the wood energy sector is estimated to contribute some 3.4 % to the national Domestic Product.

The analysis of the charcoal value chain revealed, surprisingly, that the highest profit goes to wood producers (22% of market value), followed by dealers/retailers (13%), transporters (10%) and finally charcoal makers (7%), the remaining going to taxes and costs. In fact, this supports the impression that farmers are quite interested at planting trees. From a geographic perspective, it results that 73 % of the charcoal market value goes to the production area and 27 % to the consumption area. Production areas get 81% of all costs, 90% of all taxes and 65% of all profits. Complementarily, consumption areas get 19% of all costs, 10% of all taxes and 35% of all profits.

The employment generated by the charcoal chain is considerable. Kigali charcoal market alone, produces some 18 thousand man-years of work. Since many phases of the chain are part-time rather than full time engagements, it may be assumed that Kigali charcoal market assures the livelihood, or represents the main source of the annual income, for more than 30 thousand families. Considering the whole country, it may be assumed that the charcoal chain represents the main source of income for over 50 thousand families or approximately 2.8% of the entire population.

The largest fraction of employment is generated by charcoal production (61.8%) followed by wood production (19.2%), both located in the production areas, while distribution and selling cover 6 and 12.8% of the generated employment, respectively. Considering that approximately 80% of all charcoal is produced in the Districts of Nyaruguru, Nyamagabe, Karongi and Nyamasheke, it is realistic to conclude that in these Districts the charcoal chain is a fundamental source of employment and revenue for close to 15% of rural households.

Forest regulations and taxation system

The regulatory framework is equally important, as it may inhibit, as it is often the case today, or, on the contrary, promote the development of sustainable wood energy systems. The opinion expressed by operators and stakeholders indicate that the current system tends to favour illegal logging, using uncontrolled forest exploitation and charring techniques that are less efficient and more polluting. There is an evident need for new forest regulations and taxation systems aiming at reinforcing the wood energy chain while at the same time ensuring sustainable management of resources and protection of the environment. Considering the huge relevance of the charcoal chain in the Rwandan economy, especially in rural areas, and considering that the majority of charcoal is produced from privately planted trees, it is important that future forestry and energy policies and rules aim at supporting sustainable and more efficient charcoal production. The main recommendations concerning taxation systems and harvesting rules include the following:

- Harmonization of administrative requirements, permit issuance criteria and amount of tax to be paid for harvesting.
- The forest harvesting rules (Article 67 of the Forest Law) should be integrated by specific and forest management criteria in order to render more objective and transparent the permit issuance process. These principles and criteria should be clearly explained widely publicized.
- Rules regarding harvesting of neighbouring plantations (Article 9) should be reviewed in consideration of the small size of private plantations and woodlots.
- The possibility to replace tree plantation by other farming activities (Article 11) should be reviewed in order to motivate people with unused land to establish short and medium term plantations.
- The administrative entities responsible for permit issuance should reflect the current territorial administration structure, and tree-cutting permits should be delivered at the Sector level rather than at the District level.
- There is need to harmonize the wood products taxation system at national level, to reduce the chance for irrational or excessive local interpretations. The taxes should favor the implementation of efficient charcoal production techniques and the maintenance/regeneration of tree cover.
- Establishment of a single tax for tree cutting and charcoal making, and a single tax for the transportation of wood products, in substitution of the current sets of taxies and levies.
- Support woodlots owners of plantations of 2 ha or above in the elaboration of forest management plans, as recommended by the Forest Law (Article 62). The main recommendation in this respect is that this Article be implemented systematically, in order to achieve sustainable production, rationalize administrative procedures and reduce illegal felling and illegal, and inefficient, charcoal making.

Basis of a national wood energy strategy and of a supply master plan for Rwanda

The diagnostic of wood energy in Rwanda supports the conclusion that balancing supply and demand in the nearest future is a strong priority for the whole Country and therefore priorities would not only have to concentrate on assuring a sustainable supply of Kigali. At the same time, the results indicate that the situation is not as dramatic as it was feared.

The economic relevance of woodfuel chains is considerable and most of the income and employment generation goes to poor rural areas, where such benefits are vital. Limiting the remedial action to the (realistic) reduction of the demand for woodfuels would not be able to match the demand with sustainable supply.

Hence, it is indispensable to increase the sustainable supply potential of the Country, along with improving conversion efficiency at all levels and supporting the production chains with clear and well-adapted rules and taxation systems.

Another conclusion is that the forestry information currently available is not adequate to support the operational planning level that is normally required for the design of a conventional Supply Master Plan. Particularly, forest mapping does not distinguish public from private plantations and the information on sustainable productivity of forests and other wood resources is insufficient. In fact, the inventory of the sustainable woody biomass productivity of forests, other wooded lands and farm trees (planned for 2013 in the framework of PAREF.be2) is an indispensable pre-requisite to all operational planning.

Nonetheless, the conclusions of this study provide an unprecedented basis of discussion within, and among, forestry, energy and rural development sectors for the much-needed formulation of a sound wood energy strategy for the Country as a whole. The georeferenced knowledge acquired through the WISDOM analysis forms the basis for the formulation of a national wood energy strategy as well as for the Supply Master Plan for Kigali that must be further defined and refined as adequate management information become available and the sustainability of the supply is progressively achieved, since a masterplan cannot be based on overexploitation and unsustainable supply sources.

A specific feature of WISDOM is the spatial resolution of analysis, which supports the formulation of locally tailored remedial actions.

Interventions aiming at sustainable wood energy by 2020

In order to achieve sustainable balance between supply and demand and thus progressively eliminate the deficit of 2.1 million tons of woody biomass that is expected in 2020, several possible lines of interventions were reviewed, quantifying, for each one, the contribution in filling the gap and identifying geographic areas of intervention. It is clear that no line of intervention can solve the Rwanda wood energy equation in isolation. Many actions must be combined, and the WISDOM data provides the basis for the definition of the scope and the geographic location for each intervention. Many combinations are possible and the "blending" presented below is just one of the options that appear particularly suitable:

- Interventions targeting rural and urban households and farmers, and requiring a very diffuse action:
  - *Dissemination of improved stoves*: Increase penetration of improved woodfuel stoves in 20 % of the households and support to the National Biogas Program. The number of stoves to be annually distributed in each District ranges between 1,600 and 3,000 units, for a total of 450 thousand stoves in 7 years. This would save approximately 318 kt of woody biomass (od), which represents some 15 % of the gap in 2020.
  - *Agro-forestry*: Promote tree planting in farmlands in order to achieve a 2% increase of tree cover outside forest areas. This would produce approximately 413 kt of woody biomass annually and thus contribute to fill in some 20 % of the gap. To achieve such target, over 20 million seedlings must be distributed and planted by farmers throughout the Country by 2020, with annual amounts at District level ranging between 16 and 185 thousand seedlings, depending on the availability of non-forest areas. To be noted that this seedling distribution and planting is in addition to those currently produced and planted each year to re-plant harvested areas.
- Interventions of more specific forestry character:
  - *Better management of existing forests*: Improved management of 50% of private and public plantations with priority being given to charcoal production Districts. This would increase productivity of approximately 440 thousand tons, or 20 % of the 2020 gap. This intervention should concentrate with priority on charcoal production Districts of Southern, Western and Northern Provinces, covering 90% of their planted areas.
  - *Promotion of efficient charcoal making*: Improve charring techniques on 75% of the production of the main 4 charcoal producing Districts (Nyaruguru, Nyamagabe, Nyamasheke and Karongi). The target would be to reach the annual production of 120 thousand tons of "improved" charcoal by 2020, with a saving of 630 thousand tons of wood, or 30% of the gap.

- *Creation of new plantations*: Planting of approximately 5,000 ha on areas with slope greater than 55%, located in the Northern, Southern and Western Provinces, and of some 25,000 ha in the Northern and Eastern Provinces. This would increase the supply potential of some 320 thousand tons (assuming a Medium/High Productivity), or 15% of the gap.

It should be emphasized that the effectiveness of the interventions listed above strongly depend on the regulatory framework, permit issuance and taxation systems that should be reviewed at national and at District level in order to rationalize and reinforce the forestry and wood energy sector. It is also recommended to encourage landowners to organize themselves in cooperatives, so that they may reduce the costs and increase the quality and quantity of wood production and exert a stronger influence on the price of wood products.

Other combinations of interventions are possible, reducing the demand rather than increasing the supply, or vice versa. This could be done at national level, by administrative units or on a pure geographic basis using the georeferenced WISDOM data. What must be kept in mind in any case is the impact foreseeable at national level and the goal to achieve wood energy sustainability by 2020.

Document de Synthèse

Le Rwanda est un pays peu étendu ayant une population importante qui dépend de la biomasse ligneuse comme source principale d'énergie. Ses ressources en bois sont limitées et la demande de combustibles issus du bois (« bois-énergie ») est élevée et toujours croissante, étant donné qu'à court et moyen terme ces bois-carburants resteront le seul combustible abordable pour la plupart des rwandais. La capitale Kigali joue un rôle dominant dans le cadre de l'exploitation du bois à des fins énergétiques à niveau national, avec une demande en charbon de bois qui couvre quelque 60% des besoins nationaux en cette ressource. Sans aucun doute cette forte demande en bois de feu et en charbon de bois, comme le flux constant de charbon de bois à Kigali le démontre, exerce une forte pression sur les ressources ligneuses du pays et donne lieu à des préoccupations sérieuses et généralisées sur la durabilité de l'approvisionnement.

La garantie des approvisionnements énergétiques essentiels et, en même temps, la protection de l'environnement, de la capacité productive des plantations forestières, de la végétation naturelle et des terres agricoles représentent des défis majeurs en matière d'aménagement et de planification et le Ministère des ressources naturelles, dans le cadre du programme Vision 2020 et de la Politique Forestière Nationale, a décidé de lancer l'élaboration d'un Plan Directeur pour l'Approvisionnement en Charbon de Bois et en Bois de Feu de Kigali.

Cette étude a été réalisée dans le cadre du Programme d'Appui au Développement du Secteur Forestier (PAREF.be2) cofinancé par la Belgique et le Rwanda (2012-2015) et placé sous l'autorité de la *Rwanda Natural Resources Authority (RNRA), Department of Forestry and Nature Conservation (DFNC).* Agriconsulting S.p.A. a fourni son assistance technique.

Pour encourager la formulation de stratégies opérationnelles bien organisées, les questions principales auxquelles il fallait répondre étaient les suivantes :

- Quelle est la consommation du bois de feu et du charbon de bois ?
- Quelle est la capacité de production durable ?
- Quel est l'équilibre offre-demande actuel à niveau national ? Quel sera vraisemblablement cet équilibre d'ici 2020 ?
- Où est-ce que cet équilibre sera négatif ? Et où sera-t-il positif ?
- Que peut-on faire d'ici 2020 pour atteindre un équilibre durable ? Et où faudrait-il agir pour le faire ?

Etant donné la certitude d'un équilibre offre-demande négatif à niveau national, il est immédiatement apparu que l'analyse pour l'élaboration du Plan Directeur ne pouvait pas être limitée à Kigali Ville et à ses alentours, ou aux zones, soi-disant, d'approvisionnement, mais qu'elle devait plutôt concerner un diagnostic à l'échelle nationale sur la demande actuelle et future en bois-énergie et sur le potentiel d'offre durable, ainsi qu'une réflexion approfondie des dimensions socioéconomiques de la filière bois-énergie. Afin de produire ce diagnostic à l'échelle nationale, l'analyse WISDOM[3] précédemment conduite par la FAO/NAFA (Autorité nationale de la foresterie) a été mise à jour et enrichie et une analyse socioéconomique a été conduite en utilisant les informations existantes et de nouvelles données de terrain. L'analyse WISDOM fournit une description détaillée au niveau national de la demande et de l'offre en bois-énergie en 2009 (année de référence de la carte forestière C GIS NUR) ainsi que les scénarios de 2020.. en tenant compte de la portée nationale de l'analyse, l'atelier de validation qui s'est tenu à Kigali le 17 Juillet 2013 décidé de modifier a posteriori le titre de l'étude en se référant au plan directeur d'approvisionnement de bois de feu et charbon de bois du Rwanda, plutôt que de Kigali exclusivement.

RESULTATS PRINCIPAUX:

Année de référence 2009 :

La consommation du bois de feu en 2009 était de 3,2 millions de tonnes (matière sèche), dont 88% consommées par les ménages ruraux, cette valeur incluant le bois de feu « conventionnel », composé de bois de fût et menu bois (branches), ainsi que le bois de feu « marginal », composé de bois mort, ramilles et bois de taille arboricole et utilisé par les ménages ruraux dans les zones où le bois est difficilement disponible. Bien qu'il n'y ait aucune donnée fiable sur la quantité et la distribution du bois de feu « marginal » utilisé, la distinction entre bois de feu conventionnel et marginal est bien importante dans l'analyse de l'équilibre demande-offre, étant donné que les informations sur le potentiel d'offre sont limitées aux assortiments de bois « conventionnel ».

En 2009 la consommation de charbon de bois était de 226 mille tonnes équivalent, en termes de biomasse ligneuse, à 1,5 millions de tonnes (matière sèche).

La demande totale en biomasse ligneuse en 2009 était de 4,8 millions de tonnes incluant tous les types de bois de feu, de charbon de bois et de matériaux de construction. Sans tenir compte de la fraction probable du bois de feu « marginal », la demande totale de biomasse ligneuse conventionnelle en 2009 était d'environ 4,2 millions de tonnes. La province de Kigali Ville, avec 1,1 millions de tonnes, couvrait 26% des besoins à niveau national.

Le potentiel d'offre durable en 2009 était d'environ 3,2 millions de tonnes correspondant à la variante de productivité moyenne (c'est-à-dire entre 2,6 et 4,3 correspondant, respectivement, aux variantes de productivité basse et haute). Ce niveau est sensiblement plus élevé que celui qui avait été estimé précédemment (BEST, FAO, sur la base de l'étude ISAR 2007) – cette hausse étant due aux informations fournies par la nouvelle carte forestière basée sur des photographies aériennes à haute résolution (C GIS NUR 2012), qui ont révélé une superficie planté bien plus grande que celle qui avait été estimée au départ (C GIS NUR 2007). Il faut observer que les données sur la productivité forestière sont rares aux Rwanda et, par conséquent, il est urgent et absolument essentiel de dresser à l'échelon national un inventaire des sources de biomasse ciblé sur leur potentiel de croissance durable (tel que celui qui a été prévu par le PAREF).

En 2009 le solde entre le potentiel d'offre durable (variante de productivité moyenne) et la consommation de biomasse ligneuse « conventionnelle » présentait un déficit de 870 mille tonnes, soit 21% de la demande de cette année. Il y a là un décalage important mais pas aussi marqué que celui précédemment estimé[4]. Ce

[3] La méthodologie *WISDOM (Woodfuels Integrated Supply/Demand Overview Mapping* - Carte globale intégrée de l'offre et de la demande de bois de feu) est un instrument de diagnostic et de planification à l'appui de l'aménagement de l'exploitation énergétique du bois et de la formulation de politiques, développée par la FAO (Drigo et al. 2002; FAO 2003). L'analyse WISDOM a été mise en place pour le Rwanda en 2009-2010 par la FAO/NAFA (Drigo et Nzabanita, FAO 2011) en utilisant 2006 comme année de référence.

Voir: http://www.fao.org/docrep/013/ma223e/ma223e00.pdf .

[4] La première analyse WISDOM, basée sur les informations disponibles, estimait pour l'année 2006 un déficit national de 1,8 millions de tonnes, soit 61% de la demande (Drigo et Nzabanita, 2011, pour FAO/NAFA).

niveau de déficit pourrait être à l'origine de la surexploitation des ressources existantes et causer la dégradation des forêts naturelles et des plantations. La seule façon de vérifier le taux des processus continus de dégradation et de déboisement est de réaliser une étude de suivi du couvert végétal, ce qui est fortement conseillé.

Scénarios de 2020

Deux scénarios de demande ont été considérés pour prévoir quelle pourrait être la situation en l'an 2020 :

- Un scénario de demande inchangée ou « *business-as-usual* » (BAU) décrivant la situation probable en 2020 si rien de spécial n'est fait pour changer la situation actuelle. Ce scénario s'appuie sur une hypothèse de valeurs stables de consommation par habitant et de tendance normale de pénétration des carburants de remplacement, tels que le GPL par suite de la croissance économique ;
- Un scénario de demande « améliorée » (AME), dans l'hypothèse : (i) d'une croissance de 30% de l'utilisation de foyers améliorés ; (ii) d'une plus grande efficacité dans la production de charbon de bois, et (iii) d'une plus grande pénétration du GPL dans les milieux urbains.

Selon le scénario BAU, la demande en biomasse ligneuse pour la production d'énergie et la construction en 2020 sera de 5,7 millions de tonnes (par rapport à 4,2 en 2009). Dans ce scénario la demande de la province de Kigali Ville couvrira 27% de la demande nationale.

On présume que les efforts qui seront nécessaires dans le scénario AME pour réduire la demande et augmenter l'efficacité de conversion énergétique pourront maintenir la croissance de la demande due à la croissance démographique au minimum, sans pour autant la réduire. La demande AME en 2020 est estimée à 4,4 millions de tonnes. Dans ce scénario la demande de la province de Kigali Ville sera réduite à 0,85 millions de tonnes (par rapport à 1,1 en 2009) et ne couvrira que 19 % de la demande nationale.

Pour ce qui est du potentiel d'offre en 2020, on prévoit une légère hausse des superficies plantées (quantifié ici à 10%), par suite des tendances de plantation privée et des programmes de plantation prévus tels que le PAREF. La superficie plantée en 2020 dépassera probablement les 315 mille hectares et, en supposant des valeurs de productivité moyenne, le potentiel d'offre total devrait augmenter de 3,3 à 3,6 millions de tonnes (environ 5,1 millions de m^3 de bois).

Selon le scénario de demande BAU et un potentiel d'offre « normal », en 2020 le solde sera négatif de 2,1 millions de tonnes. Cet écart correspond à 37% de la demande prévisible de 2020 et, par conséquent, l'impact attendu sur l'environnement sera considérablement plus important qu'en 2009. Une partie de cet écart pourra probablement être comblée par des produits ligneux marginaux ainsi que par une proportion plus élevée de résidus de cultures dans le bouquet énergétique ménager ; il est pourtant indubitable que l'augmentation de la demande sans un accroissement proportionnel du potentiel d'offre comportera une surexploitation ultérieure des ressources forestières. A son tour, l'utilisation accrue des résidus agricoles et des cultures pour l'énergie, au lieu de les laisser sur place, aura un impact négatif sur le cycle des substances nutritives des sols et sur la productivité agricole.

Selon le scénario de demande AME et un potentiel d'offre « normal », en 2020 le solde sera encore négatif à niveau national de 820 mille tonnes, ce qui est assez proche du niveau de 2009. Cela montre que n'intervenir que sur le côté de la demande, en améliorant l'efficacité de conversion énergétique (foyers améliorés) et les techniques de carbonisation et en subventionnant le GPL, ne peut pas résoudre la situation, mais simplement compenser l'effet de la croissance démographique et maintenir le déficit de l'offre par rapport à la demande à un niveau relativement stable.

Il est par conséquent indispensable d'agir avec une forte détermination pour augmenter également l'offre, tout en tenant compte du très bon potentiel du pays pour le faire. Par exemple, s'il était possible d'augmenter le niveau de productivité de la superficie plantée en l'an 2020 de moyen à élevé, l'équilibre entre ce niveau plus élevé de l'offre et le scénario de demande AME serait positif, avec un excédent d'environ 108 mille tonnes. A cet égard, des axes d'intervention à suivre dans les secteurs forestier et agroforestier ont été examinés ci-dessous dans le contexte d'une stratégie de bois-énergie globale afin d'augmenter l'offre et réduire, en même temps, la demande.

Quelle est la valeur du commerce en bois-énergie ?

La valeur du marché de charbon de bois au Rwanda en 2009 est estimée à 37,9 milliards de RWF, selon le prix de marché actuel, avec 22,3 milliards de RWF dans la seule zone urbaine de Kigali. L'importance économique du commerce du bois de feu est plus complexe à évaluer en termes monétaires à cause de la présence d'une forte composante informelle et d'un large éventail de prix de marché. Toutefois, en appliquant un prix modeste au bois de feu non-commercial consommé par les ménages ruraux et des prix commerciaux communs, la valeur totale du bois de feu en 2009 peut être quantifiée à 58,9 milliards de RWF. En total, on estime que le secteur de l'énergie produite à partir du bois contribue au produit intérieur brut national dans la mesure d'environ 3,4 %.

L'analyse de la chaîne de valeur du charbon de bois a étonnamment montré que la partie la plus importante des bénéfices est réservée au producteurs de bois (22% de la valeur marchande), suivis par les distributeurs/détaillants (13%), les transporteurs (10%) et finalement les producteurs du charbon de bois (7%), la partie résiduelle étant destinée aux impôts et aux frais. En effet, cela conforte l'impression selon laquelle les agriculteurs sont assez intéressés à la plantation des arbres. D'un point de vue géographique, il résulte que 73 % de la valeur marchande du charbon de bois est destinée aux zones de production et 27 % aux zones de consommation. Les zones de production supportent 81% de tous les coûts, 90% de tous les impôts et obtiennent 65% de tous les bénéfices. Par conséquent, les zones de consommation supportent 19% de tous les coûts, 10% de tous les impôts et obtiennent 35% de tous les bénéfices.

Le niveau de l'emploi créé par le charbon de bois est considérable. Seul le marché du charbon de bois de Kigali produit environ 18 mille années-homme de travail. Les phases de la filière étant des phases à temps partiel plutôt qu'à temps plein, on peut supposer que le marché du charbon de bois de Kigali représente le gagne-pain ou la source de revenu annuel principale pour plus de 30 mille ménages. A niveau national, on peut supposer que la filière du charbon de bois représente la source principale de revenu pour plus de 50 mille ménages, soit environ 2,8% de la population du pays.

La plupart des emplois relèvent de la production du charbon de bois (61,8%) suivie par la production de bois (19,2%), toutes deux situées dans les zones de production, tandis que la distribution et la vente sont respectivement à l'origine de 6 et 12,8% des emplois créés. Comme environ 80% de la quantité totale du charbon de bois est produite dans les districts de Nyaruguru, de Nyamagabe, de Karongi et de Nyamasheke, il est réaliste de conclure que dans ces districts la filière du charbon de bois est une source d'emploi et de revenu fondamentale pour près de 15% des ménages ruraux.

Réglementation forestière et système fiscal

Le cadre réglementaire est également important car il peut inhiber, comme c'est souvent le cas aujourd'hui, ou, à l'inverse, promouvoir le développement de systèmes durables de bois-énergie. Les opinions exprimées par les opérateurs et les parties prenantes indiquent que le système actuel tend à favoriser une exploitation non contrôlée des forêts consistant en l'abattage illégal et des techniques de carbonisation qui sont moins performantes et plus polluantes. Il est donc clairement nécessaire d'introduire une nouvelle réglementation forestière et des régimes fiscaux visant à renforcer la filière du bois-énergie tout en assurant une gestion durable des ressources ainsi que la protection de l'environnement. En tenant compte de l'importance primordiale de la filière du charbon de bois dans l'économie rwandaise, en particulier dans les zones rurales, et comme la plus grande partie du charbon de bois est produite à partir de lots boisés privés, il est important que les politiques et les réglementations forestières et énergétiques futures visent à soutenir une production durable et plus efficace du charbon de bois. Les recommandations principales sur les régimes fiscaux et les normes d'exploitation sont les suivantes :

- harmonisation des formalités administratives, des critères de délivrance des licences et permis et du régime fiscal appliqués à la coupe du bois;
- les normes d'exploitation des forêts (article 67 de la loi forestière) devraient intégrer des critères spécifiques d'aménagement forestier afin de rendre le processus de délivrance des permis plus objectif et transparent. Ces principes et ces critères devraient être expliqués clairement et rendus largement publics;

- les normes concernant la coupe des plantations voisines (article 9) devraient être révisées en tenant compte de la petite taille des plantations et des lots boisés privés;
- la norme concernant le remplacement de la plantation d'arbres par d'autre activités agricoles (article 11) devrait être révisée afin de motiver les exploitants ayant des terrains inutilisés à établir des plantations à court et moyen terme;
- les entités et les organismes administratifs responsables de la délivrance des permis devraient réfléchir sur la structure administrative territoriale actuelle, et les permis de coupe devraient être délivrés à niveau de Secteur plutôt qu'à niveau de District;
- harmonisation du système de taxation des produits du bois à niveau national, afin de réduire l'opportunité d'interprétations locales excessives ou irrationnelles ; les impôts devraient favoriser l'application de techniques de production de charbon de bois efficaces et le maintien ou la régénération du couvert arboré;
- nécessité d'établir un impôt unique pour la coupe des arbres et la production du charbon de bois et un impôt unique pour le transport des produits du bois, en substitution du système d'imposition actuel qui prévoit toute une série de taxes, impôts et redevances;
- soutien aux propriétaires de lots boisés ayant des plantations de 2 ha au moins dans l'élaborations de plans d'aménagement forestier, comme recommandé par la loi forestière (article 62). La principale recommandation à cet égard est d'appliquer systématiquement cet article afin d'atteindre une production durable, rationaliser les procédures administratives et réduire l'abattage illégal et la production illégale et inefficace du charbon de bois.

Base d'une stratégie nationale d'exploitation du bois à des fins énergétiques et d'un plan directeur d'approvisionnement pour Rwanda

Le diagnostic du bois-énergie au Rwanda confirme la conclusion qu'un équilibre entre offre et demande dans un très proche avenir est une priorité majeure pour le pays tout entier, pas seulement pour assurer un approvisionnement durable à Kigali Ville. En même temps, les résultats indiquent que la situation n'est pas si dramatique qu'elle n'y paraissait de prime abord.

L'importance économique de la filière du bois-énergie est considérable et la génération de revenu et d'emploi favorise surtout les zones rurales pauvres, où ces bienfaits sont indispensables. Limiter les mesures de correction à la réduction (réaliste) de la demande en bois-énergie ne pourrait pas suffire pour rapprocher la demande à une offre durable.

Il est donc indispensable d'augmenter le potentiel d'offre durable pour le pays ainsi que d'améliorer l'efficacité de conversion énergétique à tous les niveaux, tout en appuyant les filières de production avec des normes et des régimes fiscaux clairs et bien adaptés.

Une autre conclusion est que les informations forestières actuellement disponibles ne suffisent pas à soutenir le niveau d'<u>aménagement opérationnel</u> normalement nécessaire pour établir un Plan Directeur d'Approvisionnement conventionnel. En particulier, les cartes forestières ne font pas de distinction entre plantations publiques et privées et les informations sur la productivité durable des forêts et sur les autres ressources ligneuses sont insuffisantes. En effet un inventaire sur la productivité durable de la biomasse ligneuse des forêts, des autres terres boisées et des plantations arboricoles (prévu pour 2013 dans le cadre du PAREF.be2) est une condition indispensable pour tout aménagement opérationnel.

Toutefois, les conclusions de cette étude offrent une base de discussion sans précédent au sein et entre les secteurs du développement forestier, énergétique et rural pour la formulation d'une stratégie solide du bois-énergie dont le pays a désespérément besoin. Les connaissances géoréférencées recueillies par l'analyse WISDOM constituent une base pour la formulation d'une stratégie de bois-énergie nationale ainsi que pour le Plan Directeur d'Approvisionnement pour Kigali qui devra être ultérieurement défini et redéfini au fur et à la mesure que des informations de gestion adéquates seront mise à disposition et que la durabilité de l'approvisionnement sera progressivement réalisée, étant donné qu'un plan directeur ne peut pas être basé sur la surexploitation et sur des sources d'approvisionnement non durables.

Une caractéristique spécifique de WISDOM est la résolution spatiale de l'analyse qui étaye la formulation de mesures correctives adaptées à niveau local.

Interventions visant à créer une filière bois-énergie durable pour 2020

Afin d'atteindre un équilibre durable entre offre et demande et donc éliminer progressivement le déficit de 2,1 millions de tonnes de biomasse ligneuse prévues en 2020, plusieurs axes d'intervention possibles ont été examinés, en quantifiant, pour chacun d'eux, sa contribution à combler l'écart, tout en définissant aussi les zones géographiques d'intervention. Il est clair qu'aucun axe d'intervention peut résoudre l'équation de la filière du bois-énergie au Rwanda isolément. Plusieurs actions doivent être conjuguées et combinées ; à cette fin, les données WISDOM offrent une base pour définir le champ d'application et la zone géographique de chaque intervention. De nombreuses combinaisons sont possibles et la formulation présentée ci-dessous n'est qu'une option qui paraît particulièrement indiquée :

- Interventions visées aux ménages ruraux et urbains et aux agriculteurs, qui nécessitent de mesures tous azimuts :
    - *Diffusion de foyers améliorés* : augmenter la pénétration de foyers à bois améliorés pour 20 % des ménages et appui au Programme National du Biogaz. Le nombre de foyers à distribuer annuellement dans chaque district varie de 1 600 à 3 000 unités, pour un total de 450 mille foyers sur 7 années. Cela permettra d'épargner environ 318 kt de biomasse ligneuse (densité optique), ce qui représente environ 15 % de l'écart prévu pour 2020.
    - *Agroforesterie* : promouvoir la plantation d'arbres dans les terres agricoles pour permettre une augmentation de 2% du couvert arboricole à l'extérieur des zones forestières. Cela permettrait de produire quelques 413 kt de biomasse ligneuse annuellement et de contribuer ainsi à combler presque 20 % de l'écart. Afin d'atteindre ce but, plus de 20 millions de plants (semis) devront être distribués et plantés par les agriculteurs dans le pays tout entier au plus tard en 2020, avec une quantité annuelle à niveau de district comprise entre 16 et 185 mille plants selon les zones non boisées disponibles. Il convient de noter que cette quantité de plants distribués et plantés viendrait s'ajouter à celle qui est produite et plantée annuellement sur les superficies récoltées.
- Interventions ayant un caractère forestier plus spécifique :
    - *Meilleure gestion des forêts existantes* : gestion améliorée pour 50% des plantations privées et publiques, une priorité étant accordée aux districts produisant charbon de bois. Cela pourrait augmenter la productivité d'environ 440 mille tonnes, soit 20 % de l'écart d'ici 2020. Cette intervention devrait se concentrer sur les districts producteurs de charbon de bois des provinces du Sud, de l'Ouest et du Nord, qui couvrent 90% des zones plantées de ces provinces.
    - *Promotion d'une production de charbon de bois efficace* : améliorer les techniques de carbonisation pour 75% de la production des 4 principaux districts producteurs de charbon de bois (Nyaruguru, Nyamagabe, Nyamasheke et Karongi). Le but serait d'atteindre une production annuelle de 120 mille tonnes de charbon de bois « amélioré » d'ici 2020, avec une épargne de 630 mille tonnes de bois, soit 30% de l'écart.
    - *Création de nouvelles plantations* : plantation d'environ 5 000 ha sur des zones ayant des pentes supérieures à 55%, situées dans les provinces du Nord, du Sud et de l'Ouest, et d'environ 25 000 ha dans les provinces du Nord et de l'Est. Cela pourrait augmenter le potentiel d'approvisionnement de presque 320 mille tonnes (en supposant des valeurs de productivité moyenne/élevée), soit 15% de l'écart.

Il convient de souligner que l'efficacité des interventions visées ci-dessus dépend fortement du cadre réglementaire, ainsi que de critères de délivrance de permis et d'un système fiscal qui devront tous être révisés à niveau national et de chaque district afin de rationaliser et renforcer le secteur forestier et du bois-énergie. Il est également recommandé de encourager les propriétaires à s'organiser en coopératives, afin qu'ils puissent réduire les coûts et augmenter la qualité et la quantité de la production de bois et exercer une plus forte influence sur le prix des produits du bois.

D'autres combinaisons d'interventions sont possibles, par exemple réduire la demande sans augmenter l'offre ou vice versa. Cela pourrait être fait à niveau national, par unité administrative ou sur une base purement géographique en utilisant les données géoréférencées de WISDOM. En tout cas, il faut garder à l'esprit l'impact prévisible à niveau national ainsi que l'objectif de parvenir à la durabilité de la production du bois-énergie d'ici 2020.

INTRODUCTION

Securing essential energy levels and at the same time protecting the environment and the productive capacity of forest plantations, natural vegetations and farmlands represents a major planning challenge for Rwanda.

The resources are limited and the demand is high, and increasing. It is clear that in the short and medium term wood, complemented by farm residues, will remain the only affordable fuel for the majority of Rwandese population. There is also no doubt that this great demand for fuelwood and charcoal exerts a considerable pressure on the wood resources of the country, giving rise to serious and widespread concern on the sustainability of supply.

Kigali plays a dominant role in the national wood energy context, with a demand for charcoal that covers some 70% of the entire national requirement for such commodity.

Given this situation, analysis needed for the elaboration of the Master Plan for the woodfuels supply of Kigali (as defined in the original Terms of Reference, see Annex 7) cannot be limited to Kigali town and its surrounding but rather requires a comprehensive country-wide diagnostic on the current and forthcoming woodfuels demand, and on the sustainable supply potential, while a thorough analysis of the socio-economic dimensions of the wood energy sector was also required.

To produce such diagnostic, the WISDOM analysis[5] carried out in 2010 by FAO was updated and upgraded and a socio-economic analysis was carried out on the basis of all existing information and on the collection of additional field data.

In order to give time to the production of the new forest cover map of Rwanda by the Center for Geographic Information Systems and Remote Sensing (C GIS NUR), the activities were divided into two sub-phases, of which the first one, focused on the analysis of woodfuels demand and socio-economics, was carried out in April-May 2012, and the second one, that focused on the analysis of the supply potential and supply/demand balance, was executed in October-November 2012.

The results of the study were discussed at the Validation Workshop organized by RNRA/DFNC in Kigali on 17th July 2013, with the participation of numerous District Forest Officers and delegates from EWSA, NISR, REMA, donor agencies such as EU, FAO, BTC, and experts/operators of the wood energy sector. The Workshop concluded with the validation of the study and with some recommendations for the final version of the report which are now included. The Minutes of the Validation Workshop are provided in Annex 8.

The report is divided, as per PAREF request, into two main parts.

The first part (Chapter 1) is oriented to policy makers and administrators that are interested on the results of the study and on the consequent operational and policy recommendations. This part provides an overview of the countrywide diagnostic of the wood energy supply and demand situation in 2009 (baseline year of analysis) and of the expected 2020 scenarios. With reference to the expected situation in 2020, it reviews the main policy and operational options aiming at the achievement of wood energy sustainability by 2020 for Kigali as well as Rwanda as a whole. All this is intended as the basis of the supply master plan for Kigali in the context of a national wood energy strategy.

The second part (Chapters 2 and 3 and annexes) mainly oriented to wood energy planners and analysts of the forestry and energy sectors that are interested on the analytical and technical aspects of the study. It presents the analytical steps of the WISDOM analysis discussing the strengths and weaknesses of the available knowledge and assumptions made, and reviews / evaluates the range of interventions that may

[5] The methodology Woodfuels Integrated Supply/Demand Overview Mapping (WISDOM) is a diagnostic and planning tool in support to wood energy planning and policy formulation developed by FAO (Drigo et al. 2002; FAO 2003). WISDOM was implemented for Rwanda in 2009-2010 by FAO/NAFA (Drigo and Nzabanita, FAO 2011).
See: http://www.fao.org/docrep/013/ma223e/ma223e00.pdf .

contribute to fill in the woodfuel gap expected in 2020. This part presents as well the results of value chain analysis, while the details of the surveys carried out and all other technical references are put in annexes.

This preferred layout for reporting, meant to render the two parts separately usable by different stakeholders, has implied as a consequence a certain degree of overlapping and repetition of concepts needed in both parts for full comprehension of the text.

Scope and objectives of the study

This study was carried out in the framework of the Support Program to the Development of the Forestry Sector (PAREF.be2), supported by Belgium/Rwanda (2012-2015), under authority of the Rwanda Natural Resources Authority (RNRA), Department of Forestry and Nature Conservation (DFNC).

Among the anticipated outputs of the mission, the original ToR included the elaboration of the Supply Master Plan for Kigali (see Annex 7). However, as discussed in the Technical Proposal presented by Agriconsulting, which forms the current accepted basis of the activity, it was made clear that the negative national-level balance between the sustainable wood supply and the woodfuel demand prevents the elaboration of a separate solution for Kigali in isolation from the national context (Annex 7).

In fact, a supply masterplan cannot be based on overexploitation and on unsustainable supply sources. The focus of the analysis was therefore re-oriented to the entire Country with the objective of defining the set of interventions necessary to achieve a sustainable wood energy condition for the country as a whole.

In consideration of the national scope of the analysis, the Validation Workshop deliberated to change post-facto the title of the study by referring to the Supply Master Plan for Firewood and Charcoal of Rwanda, rather than Kigali (see Annex 8).

The overarching scope of this study was therefore to concentrate on enabling wood energy planning in Rwanda, though still with special attention to Kigali, in order to review policy options vis-à-vis the expected 2020 scenarios.

More specifically, the scope was meant to provide a decision making tool for planning and monitoring districts forest resources management for a sustainable supply of woodfuels of Kigali ass well as of the rest of the Country.

Immediate objectives of the activity were consequently focused on:

- Updating and enhancing the WISDOM analysis of Rwanda for sustainable forest management and strategic wood energy planning.
- Analyzing the current woodfuel supply and demand and outline 2020 scenarios.
- Analyzing the value chain of fuelwood and charcoal with focus on Kigali and assessing the pros and cons of current taxation systems.

Concerning the planning level that is currently feasible, it may be noted that the information available on woodfuels demand and supply potential (already existing or collected for this study) is considered adequate to support strategic planning of wood energy in Rwanda and the formulation of viable locally-tailored policy options, which are fundamental pre-requisites to further operational planning.

It should also be emphasized, however, that the current state of knowledge is not yet adequate to support detailed resource management planning. Particularly, the available forest map does not distinguish public plantations from private plantations and the information on the sustainable productivity of forests and other wood resources is insufficient.

In practice, the current forestry data cannot support the operational planning level that is normally required for the design of a conventional Supply Master Plan. For such scope, the inventory of the sustainable woody biomass productivity of forests, other wooded lands and farm trees (planned for 2013 in the framework of PAREF.be2) is an indispensable necessity.

Nonetheless, the conclusions of this study provide an unprecedented basis of discussion within, and among, forestry, energy and rural development sectors for the much-needed formulation of sound wood energy strategies for the Country as a whole.

This national wood energy planning context forms the basis of a preliminary Supply Master Plan for Rwanda that must be further defined and refined as adequate management information become available.

1. BASIS OF A SUPPLY MASTER PLAN IN THE CONTEXT OF A NATIONAL WOOD ENERGY STRATEGY

1.1 DIAGNOSTIC OF WOODFUELS DEMAND AND SUPPLY IN 2009 AND 2020 SCENARIOS BASED ON WISDOM

The following sections provide only an overview of the results and conclusions of the WISDOM analysis for 2009, baseline year of analysis, and 2020 scenarios, that have policy relevance. The same overview is provided for the conclusion of the socio-economic survey and value chain analysis. The results and main conclusions are presented in form of "bullets" in order to provide the most relevant outcome of the analysis as self-contained as possible.

The detailed description of the update and upgrade of WISDOM Rwanda for 2009 and 2020 scenarios is given in Chapter 2 of this report, while the socio-economic survey and value chain analysis are discussed in Chapter 3 and relevant Annexes, to which we refer for all methodological aspects, survey features, description of the assumptions made and all other technical details.

1.1.1 Woodfuels demand in 2009

- The estimated consumption of woody biomass for energy and construction material in 2009 is 4.8 million tons (dry matter, approximately 6.86 million m^3 of wood). This includes consumption in the residential, industrial, public and commercial sectors. Sawnwood consumption is excluded.
- Part of this wood, however, is not made by stem wood or branch wood, which are "conventional" wood assortments used as fuelwood or for charcoal, but are rather made of collected deadwood, twigs, smaller branches from annual pruning of farm trees and shrubs, which are wood assortments usually excluded from forest inventories and thus not accounted for among the conventional supply sources. These "marginal" wood assortments are commonly used as fuelwood in rural areas where conventional wood is scarce. It is not known what fraction of the demand for fuelwood is satisfied by "marginal" wood, nor what is its sustainable production potential. In the attempt to quantify its contribution, in this study we assumed that marginal wood replaces conventional wood in the rural areas where the available conventional wood (within a 4-km radius) is insufficient to satisfy the demand. Conservatively, we set the replacement fraction to 30% of the demand, as a maximum.
- By revising the consumption of fuelwood in rural areas where wood resources are scarce, the total demand for "conventional" wood in Rwanda for energy and construction material in 2009 is estimated to be **4.2 million tons** (approximately **6 million m^3 of wood**), as shown in Table 1. This is the wood demand that has to be confronted to the "conventional" wood supply potential in order to estimate and map the supply/demand balance.
- The Province of Kigali is the stronger consumer, with 26 % of the entire woodfuels consumption, in spite of its small size, followed by Southern Province (22 %) and Western Province (21 %).

1.1.2 Woody biomass supply potential in 2009

- The new forest map produced by CGIS-NUR and released in October 2012 revealed a plantation area far greater than that previously estimated. This new map is considered more reliable than previous ones, thanks to the high spatial resolution of the source data. The new map represents an important improvement in the understanding of Rwanda's woody biomass supply sources.

- The available data on the annual increment of plantations and natural forest formations does not support the accurate estimation of the sustainable supply potential, which is the quantity of woody biomass that can be annually produced on a sustained basis maintaining at the same time the productive capacity of natural or man-made forest and shrub formations. However, based on the limited data on eucalyptus plantations and few other species, Low and High productivity variants were estimated, from which a Medium productivity variant could be defined as mid-range value, which may be considered realistic until new evidence is produced.
- According to the Medium productivity variant, the estimated sustainable supply potential in 2009 is 3.3 million tons (dry matter, approximately 4.75 million m^3 of wood), as shown in Table 1. The Southern Province accounts for 41 % of the whole supply potential, followed by the Western Province (29 %) and by the Northern Province (15 %).
- Planted forests are the main source of woody biomass for energy and construction material, accounting for 80% of the supply (2.65 million tons). Eucalyptus species make 91 % of all plantations (as pure stands or eucalyptus-dominated stands), and produce 72 % of all woody biomass consumed in the Country.
- Agro-forestry sources of woody biomass such as trees outside forest (TOF) and micro woodlots (below 0.25 ha) are important sources of fuelwood and wood for charcoal throughout the Country. Using plantations' productivity as indicative reference, the estimated supply potential of these agro-forestry sources is 0.61 million tons, tentatively. To be noted that this productivity is limited to "conventional" wood assortments, excluding other assortments such as collected deadwood, twigs, smaller branches from periodic pruning of farm trees and shrubs, that, although "marginal" from a commercial perspective, do play a crucial role in the energy economy of rural households.
- Natural shrub formations cover significant areas in the eastern part of the Country. Their woody biomass supply potential is estimated at 51 thousand tons (dry matter). There is no data about shrub stock and productivity in Rwanda and this estimate should be considered tentative and probably conservative.

1.1.3 Supply/demand balance in 2009

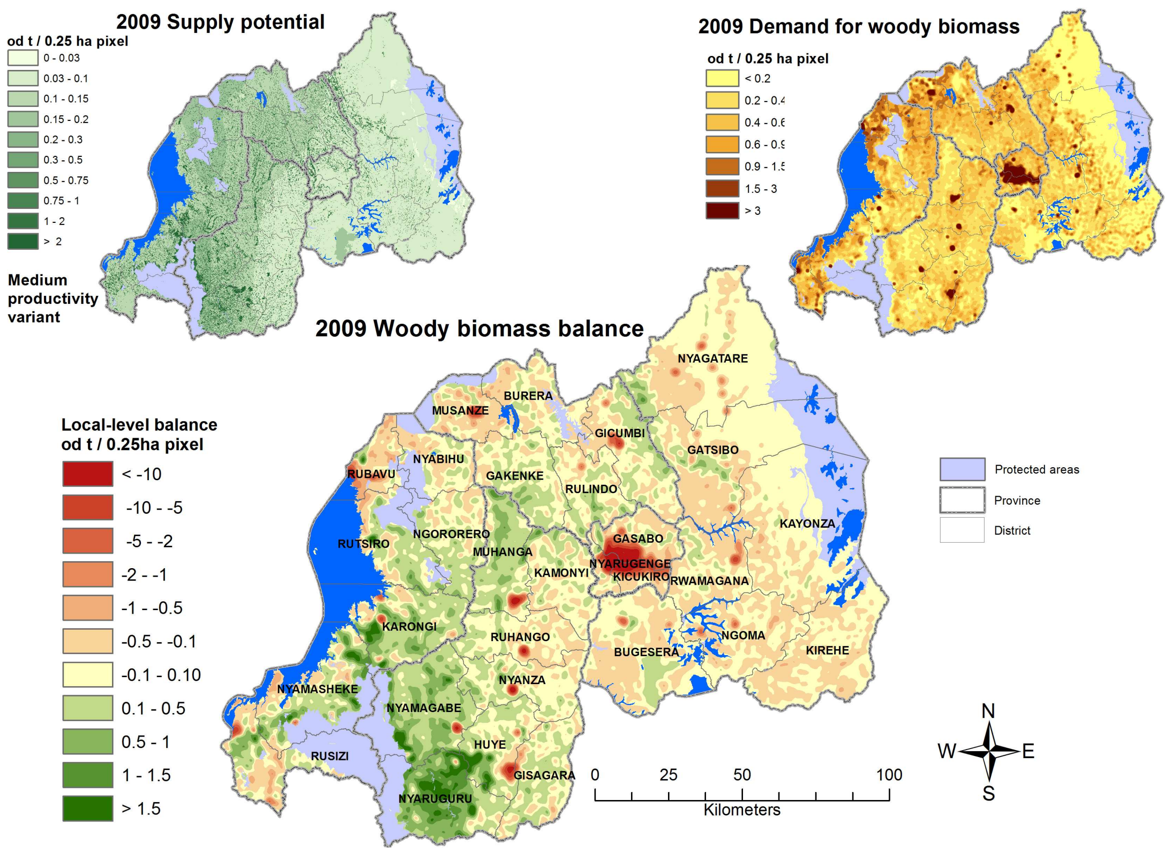
- The supply/demand balance in 2009 shows a national deficit of 870 thousand tons (dry matter, approximately 1.2 million m^3 of wood), as shown in Table 1. This means that approximately 21% of the total woody biomass consumed is non-sustainable and/or is satisfied by marginal sources of biomass not included in the supply potential. This deficit is not trivial, but is much smaller than previously estimated (i.e., when the total plantation area was thought to be only 40% of its actual area).
- The provinces with surplus values are the Southern (+ 431 thousand tons) and the Western (+ 82 thousand tons) provinces, which are in fact the sources of the charcoal and fuelwood consumed in Kigali and other urban centers.
- The provinces with deficit values are Kigali City, with a deficit of 1 million tons, followed by the Eastern (- 290 thousand tons) and the Northern (-80 thousand tons) provinces.

Table 1: Province-wise summary of 2009 woody biomass supply potential, demand for woodfuels and construction material and supply/demand balance, assuming a 'medium' productivity of the standing woody biomass. Units are thousand tons (kt) oven dry (od) woody biomass equivalent)

	2009 Available supply potential [a]	**2009 Demand [b]**	**Balance 2009 [c]**
Province	Woody biomass Medium productivity variant (kt od)	Fuelwood, wood-for-charcoal and construction material (kt od)	Available supply potential <minus> Demand (kt od)
Kigali City	85	1,099	**-1,014**
Southern	1,354	923	**431**
Western	979	897	**82**
Northern	524	603	**-80**
Eastern	385	674	**-290**
Tot Rwanda	**3,327**	**4,197**	**-870**

[a] The supply potential here considered includes the fraction of the annual increment of woody biomass (medium productivity variant) that is physically and legally accessible and available for energy and construction material. Sawnwood is excluded but sawmill residues are included. The supply potential is limited to the "conventional" woody biomass (stem and branches from tree harvesting), excluding "marginal" fuelwood sources such as twigs, periodically pruned branches and deadwood, and crop residues.
[b] Similarly, the Demand for woodfuels is limited to "conventional" fuelwood and wood for charcoal and construction material, excluding "marginal" fuelwood sources and crop residues.
[c] Balance resulting from the available supply potential of conventional wood and the demand for conventional woodfuels and construction material.

Figure 1: Cartographic overview of 2009 woody biomass supply potential[a], woody biomass demand[b] and supply/demand balance[c] in a local context of 2km.



a b c See notes under Table 1.

1.1.4 2020 supply and demand scenarios

Demand 2020

- In forecasting the consumption situation to 2020 two main scenarios were considered:
    - a business as usual (BAU) scenario that is meant to depict the probable situation in 2020 if nothing special is done to change the current situation. The same per capita consumption values are applied to the estimated 2020 population and the trend observed in the penetration of alternative fuels, such as LPG, as an effect of economic growth, is maintained.
    - an "ameliorated" (AME) scenario, assuming: (i) a 30 % increase in the penetration of improved fuelwood and charcoal stoves in rural and urban areas; (ii) a higher efficiency in charcoal production from the current 12% to 18% yield, and (iii) a higher, but realistic, penetration of LPG in the energy mix of urban households, bakeries and restaurants, schools, detention centers, etc.
- According to the BAU scenario, the demand of woody biomass for energy and construction will be 5.7 million tons (from the 4.2 of 2009), as shown in Table 2. In this scenario the demand in Kigali City Province will cover 27 % of the national demand.
- The AME scenario, with all the assumed efforts to decrease the demand and increase conversion efficiencies, will only be able to maintain the growth of the demand to a minimum, but will not be able to actually reduce the demand. The AME demand in 2020 is estimated to be 4.41 million tons (Table 2). In the AME scenario the demand in Kigali City Province will be reduced to 855 thousand tons (from the 1099 tons of 2009), covering only 19 % of the national demand.

Supply 2020

- Without considering new particular interventions, it may be assumed that the plantation area in 2020 will be slightly larger than that reported in the forest map (depicting 2009 situation). A 10% increase in plantation area in 2020 was considered reasonable on account of the plantations that existed but were not yet visible in 2009 orthophotos, as effect of private planting trends and of the foreseen planting programs, such as PAREF. Therefore, without additional interventions, the plantation area in 2020 is expected to be 315,500 hectares and, assuming Medium Productivity, the overall supply potential is expected to increase from 3.3 to 3.59 million tons (dry matter, approximately 5.13 million m^3 of wood). This is what we may consider the "normal" 2020 supply scenario.

2020 Supply/demand balance

- The 2020 balance according to the BAU Demand scenario and "normal" supply potential will show a deficit of 2.1 million tons. While part of this gap may be filled in by marginal wood products and by a higher proportion of crop residues in the household energy mix, it is indubitable that the increased demand without a proportionate increase of the supply potential will induce overexploitation of forest resources. In turn, the increased use of farm and crop residues for energy rather than leaving them in situ will have a negative impact on the soil nutrients cycle and farm productivity.
- According to the AME Demand scenario and "normal" supply potential the balance in 2020 will still show a national-level deficit of 820 thousand tons, which is quite close to that of 2009. This shows that operating only on the demand side by improving energy conversion efficiency (improved stoves), charring techniques and subsidizing LPG, cannot resolve the situation, but can merely offset the effect of population growth and maintain the supply/demand balance situation relatively stable. **Hence, for this reason, and for other reasons that will be discussed below, it is indispensable to operate on the supply side as well.**

Table 2: Province-wise 2020 scenarios of woody biomass supply potential, demand for woodfuels and construction material (in form of woody biomass equivalent) and supply/demand balance. Business-as-usual (BAU) and ameliorated (AME) demand scenarios are considered vis-à-vis the expected 2020 "normal" supply potential.

Values are '000 tons, dry matter	2020 "normal" supply potential	2020 Demand - BAU scenario	Balance 2020 - BAU	2020 Demand - AME scenario	Balance 2020 - AME
Province	Medium productivity variant (kt od)	BAU demand for woodfuels and construction material (kt od)	based on BAU demand and "normal" supply (kt od)	AME demand for woodfuels and construction material (kt od)	based on AME demand and "normal" supply (kt od)
Kigali City	92	1,537	-1,445	855	-763
Southern	1,470	1,241	230	1,026	444
Western	1,059	1,165	-106	992	67
Northern	564	755	-190	666	-102
Eastern	405	1,003	-598	871	-466
Tot Rwanda	**3,590**	**5,700**	**-2,110**	**4,410**	**-820**

See notes under Table 1 for a description of *Supply potential*, *Demand* and supply/demand *Balance*.

1.1.5 Woodfuels trade, charcoal value chain and employment generation

- Value of the charcoal market of Rwanda in 2009 is estimated at 37.9 billion RWF, according to current market price, with 22.3 billion RWF in the urban area of Kigali only, as shown in Table 4.
- More complex is to assess in monetary terms the economic magnitude of fuelwood trade due to the strong informal component and to the wide range of market prices. However, allocating a small price for the non-commercial fuelwood consumed by rural households and applying common commercial prices to various fuelwood assortments, the total value of fuelwood in 2009 may be quantified at 58.9 billion RWF, or 106.9 million US$, as shown in Table 3.
- Considering a 2009 GDP of 5,200 Million US$, the wood energy sector contributed some 3.4 % to the national Domestic Product.

Table 3: Province-wise summary of charcoal and fuelwood trade (HH = households)

	Charcoal trade 2009			Fuelwood trading 2009				
	Rural	Urban	Total	Rural HH Non-commercial	Rural HH Commercial	Urban HH Commercial	Other uses [a]	Total
Province	Million RWF			Million RWF				
Kigali City	1,923	22,288	24,212	248	258	4,040	415	4,961
Southern	1,016	3,487	4,502	4,490	4,677	5,629	830	15,626
Western	4,025	1,171	5,196	4,715	4,912	4,161	846	14,635
Northern	939	857	1,795	3,623	3,774	3,044	909	11,352
Eastern	1,628	566	2,194	4,853	5,055	2,012	392	12,312
Tot Rwanda	**9,530**	**28,369**	**37,900**	**17,930**	**18,677**	**18,886**	**3,392**	**58,885**

[a] Major other uses include: secondary schools, prisons, brick makers and tea factories.

- The charcoal value chain (relative to Kigali market) in Table 4 shows that, assuming a medium productivity of plantations and 8 year rotations, the highest profit goes to wood producers (22% of market value), followed by dealers/retailers (13%), transporters (10%) and finally charcoal makers (7%).

- Summarizing the value chain by location (production or consumption area), it results that 73 % of the charcoal market value goes to the production area and 27 % to the consumption area. Production areas get 81% of all costs, 90% of all taxes and 65% of all profits. Complementarily, consumption areas get 19% of all costs, 10% of all taxes and 35% of all profits.
- The analysis of the man-days of work needed in the various phases of charcoal production, distribution and sale processes revealed that the employment generated by the charcoal chain is considerable.
- One ton of charcoal sold at the market requires approximately 38 man-days of work. Kigali charcoal market alone implies some 18 thousand man-years of work. Since many phases of the chain are part-time rather than full time engagements, it may be assumed that Kigali charcoal market assures the livelihood, or represents the main source of the annual income, for more than 30 thousand families.
- Considering the estimated 27.8 thousand man-years of employment generated for the whole country, it may be assumed that the charcoal chain represents the main source of income for over 50 thousand families or approximately 2.8% of the entire population.

Table 4: Charcoal value chain

	Charcoal value chain			Job generation	
	Percent of final market value	**2009 Kigali market only**	**2009 whole Rwanda**	**1 ton charcoal**	**2009 whole Rwanda**
	%	Billion RWF	Billion RWF	**Man Days**	**Man years**
Production cost for trees (seedlings, planting, maintenance, value of land)	10.2	2.47	3.77		
Profit for wood producer	22.2	5.37	8.21		
Total wood production	**32.4**	**7.84**	**11.98**	**7.3**	**5,354**
Cost for a tree cutting permit paid to the District (production)	1.2	0.29	0.44		
Other taxes and royalties paid to the District (production)	3.4	0.82	1.25		
Cost for manpower	14.6	3.53	5.40		
Profit for a charcoal producer	6.8	1.65	2.52		
Total Charcoal production	**26.0**	**6.29**	**9.61**	**23.6**	**17,206**
taxes and royalties paid by distributor to District (production place)	4.1	1.00	1.53		
taxes and royalties paid per ton to the District (selling)	0.3	0.07	0.11		
Expenses for distribution other than taxes per ton	12.2	2.96	4.53		
Profit for Distributor	9.7	2.35	4.48		
Total Distribution	**26.4**	**6.39**	**10.66**	**2.3**	**1,714**
taxes and royalties paid to District	0.6	0.16	0.23		
expenses other than taxes and royalties	1.3	0.32	0.41		
profit for charcoal dealer	13.3	3.22	5.01		
Total dealer/retailer	**15.3**	**3.70**	**5.65**	**4.9**	**3,567**
Total	**100.0**	**24.21**	**37.90**	**38.2**	**27,841**

- The largest fraction of employment is generated by charcoal production (61.8%) followed by wood production (19.2%), both located in the production areas, while distribution and selling cover 6 and 12.8% of the generated employment, respectively.

- Considering that approximately 80% of all charcoal is produced in the Districts of Nyaruguru, Nyamagabe, Karongi and Nyamasheke, it is realistic to conclude that in these Districts the charcoal chain is a fundamental source of employment and revenue for close to 15% of rural households.

1.2 STRATEGIC PLANNING OPTIONS

While much of the industrialized world is embracing biomass energy as a pillar of low-carbon growth, it seems rather odd that a country like Rwanda, which depends on woodfuels produced primarily from privately planted trees, assigns low priority to wood energy and that, rather than supporting the sustainable development of biomass energy, seeks instead a conspicuous downgrade[6]. We must recognize that in this policy vision the Country is not isolated. In fact, in most countries of sub-Saharan Africa (SSA) biomass energy is granted a very low policy profile in spite of its paramount role in both energy and forestry contexts (Owen et al. 2012). In most SSA countries biomass energy is viewed as "traditional" (an euphemism for *obsolete*), dirty and inefficient and generally perceived as responsible for deforestation and degradation processes. The latter being probably the main factor behind the negative perception of wood energy in the energy policy of Rwanda.

The issue is: is it justified? Given the limited extent of natural forests in Rwanda at this point of time, and the fact that these are almost entirely protected, and given that the main sources of fuelwood and charcoal are planted trees (private, mostly), Rwanda should be far less worried about deforestation and forest degradation than all other SSA countries. But still, the negative perception remains. Why? We suspect that the main reason is that the woodfuels production system and the woodfuels value chain are not well understood. Incomplete and/or distorted information on the woody biomass production potential vis-à-vis the evidence of a huge, and growing, demand has prompted a vision of degradation and deforestation as the IMPLICIT and OBVIOUS consequence. So obvious, in fact, that no proof appears necessary.

That such negative perception exists in the energy sector is somehow understandable, given the limited familiarity in such sector with biomass sources and sustainability. Much less justified is that such prejudicial vision is shared in the forestry sector as well. The forestry sector should take up the challenge and provide clear evidence on the potential, and limits, of sustainable wood production and monitor Rwanda's forest cover in order to assess -objectively- processes of deforestation and degradation caused by woodfuels production.

1.2.1 The knowledge base for planning

With the purpose of creating a solid knowledge base for strategic planning, the current supply potential and woodfuels consumption, and possible 2020 scenarios were analyzed applying the WISDOM model to the most recent data available.

According to this analysis deficit in 2009 was 21% of the demand, which is not trivial but it is significantly lower than previously estimated (61% of demand, FAO/NAFA 2011), thanks to a much larger plantation area resulting from the latest forest map (CGIS 2012). In addition, the 20% gap in 2009 may be pessimistic since there are coping strategies implemented by rural households, such as annual pruning of trees and shrubs, whose contribution to fill in rural households energy needs is not yet determined but assumed to be relevant. It should be noted, in fact, that current knowledge on the sustainable productivity of forest resources is rather limited and that of trees outside forest is totally absent, which may induce a certain underestimation of the actual supply potential.

In order to set clear planning targets and to guide the review of possible interventions and policy options, Table 5 summarizes the main parameters that characterize the demand and supply potential in 2009 and 2020 according to BAU and AME scenarios, and the consequent balances.

[6] The Energy Sector Strategic Plan (ESSP) 2012-2017 (Ministry of Infrastructure, October 2012), reflecting Government's Vision 2020, indicates the target of reducing biomass energy by 50% through promotion of alternative energy sources (electricity, LPG, biogas, etc…). The strategy described in this ESSP document seems to be mainly focused on the development of new alternative energy sources, while neglecting fuelwood and charcoal production, which nonetheless play an essential role in national energy supply, being the most strategic energy sources for the rural population as well as for the urban poor.

Table 5: Selected parameters that characterize the woodfuels supply and demand in 2009 and in 2020 according to BAU and AME scenarios

	2009 situation	2020 Scenario BAU	2020 Scenario AME
Plantations productivity (od t/ha/year)	9,5	9,5	12.4
Population growth rate	= current rate	= current rate	= current rate
Productive plantation area		+10%	+10%
Use of improved fuelwood stoves : urban area	60%	60%	90%
rural area	50%	50%	80%
Use of improved charcoal stoves : urban area	70%	70%	100%
rural area	50%	50%	80%
Use of LPG: - Kigali	7.6%	15%	30%
- Other urban areas	2-3%	4%	10%
Carbonization rate (charcoal making)	12%	12%	18%
Agro-forestry: trees outside forest = 5.2 % land cover	5.2%	5.2%	5.2%
Supply ('000 tons, dry wood equivalent) [a,b]	**3.327**	**3.590** [a]	**4.650** [b]
Demand ('000 tons, dry wood equivalent)	**4.197**	**5.700**	**4.542**
Balance ('000 tons, dry wood equivalent)	**-870**	**-2.110**	**+108**

[a] The 2020 Supply in the BAU scenario is estimated assuming 10% increase of the 2009 planted area and Medium productivity (see 1.1.4 above).
[b] The 2020 Supply in the AME scenario is estimated assuming 10% increase of the 2009 planted area and High productivity.

The table above presents the results of the supply/demand of woody biomass by 2020 according to two scenarios:

- The first scenario (BAU= Business As Usual) considers the same parameters of production and consumption in 2020 as those currently estimated, the only change being the population growth (cf. the current growth rate) and an increase in forest cover of 10%. In other words, this scenario is equivalent to a scenario where nothing changes in the consumption habits and in the techniques and methods for wood and charcoal production. In this scenario an important disequilibrium arises between supply and demand in 2020 (demand 58% greater than the sustainable production capacity), which will inevitably lead to overexploitation and resource degradation.
- The second scenario (AME = Ameliorated), considers a combination of a realistic positive evolution of all important production and consumption parameters (widespread use of improved stoves, use of modern carbonization systems, improved forest productivity, improved LPG penetration, etc…) but without additional plantations nor agro-forestry inputs. In this scenario, estimates show that a near balance between supply and demand can be reached in 2020.

1.2.2 Itemized review of most promising interventions

The "package" of interventions presented in the AME scenario is not the only possible solution since it doesn't include all lines of interventions. As a matter of fact, the AME scenario does not include the impact of additional plantations nor the planting of more trees through agro-forestry programs.

It is in fact recommended that the final planning of remedial actions be locally tailored, selecting from the folder of all possible solutions/interventions those that are best adapted to local conditions and needs. Cost-efficiency and interactions among interventions must be carefully evaluated, and assessing the efficiency of each line of interventions in filling in the deficit of 2.1 million tons expected in 2020, is an important first step.

Table 6 summarizes the impact on the expected balance between supply and demand in 2020 of several lines of intervention relative to production and consumption of woodfuels. In order to understand the potential of each action, the simulations were carried out for each parameter separately, keeping all other aspects unchanged.

This list is not exhaustive. There are other actions, such as the promotion of biogas, that deserve due attention and that in time will grow as true fuel alternatives. The actions here considered is limited to those whose impact is likely to be strong enough in the 2020 timeframe.

Table 6: Expected impact of various lines of intervention on the probable 2020 woodfuel gap of 2.1 million tons

Production/ consumption parameter	Hypothesis of improvement between 2009 and 2020	Potential impact on the reduction of the gap of 2.1 Mt in 2020	Additional strategic aspects
Improved stoves	% of use by households →+30%	**22.6 %**	On the entire national territory. Benefits include improved indoor air quality and health
More efficient charcoal making	Carbonization rate : 12% →18%	**40.0 %**	Actions must focus on the production Districts (those with an energy wood excess = Nyaruguru, Nyamagabe, Nyamasheke, Karongi, etc). Required : organization and regulation of the chain and implementation of a new taxation system to encourage the use of modern techniques
Promotion of LPG in urban areas	% of use by households: Kigali: 15% → 30% Other towns : 4% →10%	**11.0 %**	Primarily in Kigali and large towns. Rapid impact but requiring subsidy on imported gas. Uncertainty on the economic sustainability and risk of return to charcoal when subsidies cease.
Better management of existing forests	Forest productivity: 9.5 → 12.4 od t/ha/year	**42.3 %**	On the entire national territory. Silvicultural actions would include: farmers access to optimal genetic resources and support in the selection of suitable species; training on good nursery, planting and maintenance practices; farmers' access to fertilizers needed to integrate soil nutrients; clear prescriptions and training on felling practices; optimized rotation systems oriented to the production of the required wood assortments; etc. Full effect of the action will arrive after 2020.
New Plantations	Creation of 30,000 ha of new plantations	**15.5 %**	Priority: - Districts with a production deficit, particularly those of the Eastern and Northern Province - Areas with steep slopes
Agro-forestry (increase of tree cover)	Coverage of trees out of forests: 5.2% → 8.2%	**29.3 %**	On the entire national territory: Priority: - Districts with a production deficit, particularly those of the Eastern and Northern Province - Districts with not enough space for true reforestation - Areas with steep slopes

Note: The impacts in % as presented in the table are considered separately for each isolated production and consumption parameter. These impacts cannot be added up arithmetically since they may interfere with each other.

Table 7 presents one possible "Blending" of interventions, among the many possible combinations, aiming at filling the 2020 woodfuel gap of 2.1 million tons.

Table 7: "Blending" of interventions, among the many possible combinations, aiming at filling the 2020 woodfuel gap of 2.1 million tons

Lines of intervention	Pros and Cons	Possible "blending" of interventions by 2020: % of 2.1 Mt gap filling	Possible "blending" of interventions by 2020: Objectives and remarks
Improved stoves	**Pros:** Improved indoor air quality and health **Cons:** Huge program with relatively limited impact	**15 %**	20% additional penetration. Concentrate on charcoal stoves in urban areas and on fuelwood stoves in rural areas
More efficient charcoal making 12% →18%	**Pros:** Substantial impact; Consolidation of income and employment in rural areas **Cons**: Must proceed in combination with forest management	**30 %**	Focus on 75% of charcoal production in Nyaruguru, Nyamagabe, Nyamasheke and Karongi, Districts. Create favorable tax & permit system rewarding efficiency and sustainability; promote cooperatives of producers.
Promotion of LPG in urban areas	**Pros:** Rapid response **Cons:** Limited impact; non-renewable; requiring subsidies on imported oil products; uncertainty on the economic sustainability; risk of return to charcoal when subsidies cease.		LPG use will "naturally" increase in wealthier urban households. It seems preferable to promote biogas in rural areas and in all suitable situations instead.
Better management of existing forests	**Pros:** Substantial impact; consolidation of income and employment in rural areas. **Cons:** Relatively slow impact	**20 %**	Improved management of 50% of the plantation. Supporting private and public forestry has paramount importance; the inventory of biomass resource is a pre-requisite; priority areas are charcoal production sites
Creation of new plantations	**Pros:** Soil protection in steep slope areas; increased supply in forest-poor areas **Cons:** Difficulty to find suitable plantation areas; impact rather limited and relatively slow	**15 %**	Establishment of approx. 30 thousand ha in deficit areas in Eastern and Northern provinces and in steep slope areas, if feasible according to land use and ownership.
Agro-forestry (increase of tree cover)	**Pros:** Soil protection in steep slope areas where plantations are not feasible; increased supply in forest-poor areas; substantial impact **Cons:** Very diffuse action; difficulty to quantify the impact	**20 %**	Create 2% tree cover in rural areas. Support coping strategies undertaken by farmers; promote planting of trees and woodlots from good seeds in farmlands. Priority areas: deficit areas of Eastern province and on steep slopes of Northern, Southern and Western provinces
		100 %	

1.2.3 Forestry rules and taxation system

The regulatory framework is equally important as it may inhibit, as it is often the case today, or, on the contrary, promote the development of sustainable wood energy systems. The opinion expressed by the interviewed operators and stakeholders indicate that the current system tends to favor illegal logging, using uncontrolled forest exploitation and charring techniques that are less efficient and more polluting. The need is evident for the definition and implementation of new forest regulations and taxation systems aiming at reinforcing the wood energy chain while at the same time ensuring sustainable management of resources and protection of the environment.

Considering the huge relevance of the charcoal chain in the Rwandan economy, especially in rural areas, and considering that the majority of charcoal is produced from privately planted trees, it is important that future forestry and energy policies aim at supporting sustainable charcoal production and at making the charring processes more efficient, rather than limiting it. Concerning taxation systems and harvesting rules, the following points are recommended:

- Improvement of taxation strategy should be achieved by reviewing the Forest Law and the instructions regarding its implementation. The revision should focus on the harmonization of administrative requirements, permit issuance criteria and amount of tax to be paid for harvesting.
- The Forest Law and the relevant prescription regulating forest activities should be improved for clarity and presented/explained widely. In particular, the general principles of sustainable forest management concerning forest harvesting (Article 67) should be integrated by detailed and objective criteria in order to render more objective and transparent the permit issuance process. These principles and criteria should then be widely publicized and clearly explained, targeting with priority tree plantations owners, farmers and local authorities.
- Prescriptions regulating forest harvesting should be reviewed considering that the majority of the plantations are very small. Particularly, rules regarding minimum distance between two parcels to be harvested and the time gap requested before harvesting neighboring plantations (Article 9) should be reduced/adapted in consideration of the small size and fragmentation of private plantations and woodlots.
- The possibility to replace the tree plantation by other farming activities (Article 11) should be reviewed in order to motivate people with unused land to establish short and medium term plantations.
- Administrative bodies defined in the Forest Law as responsible for permit issuance should be rationalised to reflect the current territorial administration structure, with the scope of simplifying the administrative procedures and of making them more easily accessible to woodlot owners. Specifically, it is recommended that tree-cutting permits be delivered at the Sector level rather than at the District level. This means that, in order to avoid overexploitations, the issuance of cutting permits must comply with Sector-level management plans and clearly defined quotas that must be prepared for all Sectors, and the applications of good-practice rules and obligations defined by the Forest Law, including the commitment to replace cut trees.
- The Forest Law and wood products taxation system should clearly fix the amount of taxes to be paid and all administrative requirements in order to harmonize them at national level and thus reduce the chance for irrational/conflicting local interpretations. The amount to be paid should not only be proportional to the quantity cut, produced and/or transported but should also favor the implementation of efficient production techniques. For instance, higher charges should be applied to those who use inefficient techniques and who are going to replace tree plantations with different land uses.
- In order to simplify the administrative procedure, reduce costs and increase income of the central and local governments, it seems appropriate to establish a single tax for tree cutting and/or charcoal making and a single tax for transportation of wood products, in substitution of the current array of taxies and levies.
- Most important, as already recommended by the Forest Law (Article 62), the woodlots owners of plantations of 2 ha or above should be supported to elaborate a forest management plan. The forestry agency should support woodlot owners and communities to get their own forest management plan and establish forest management committees. The main recommendation in this respect is that this Article be implemented as systematically as possible, since the development and implementation of management plans is the only way to achieve sustainable production and guarantee application of appropriate silvicultural techniques. Management plans will streamline and rationalize all administrative procedures and will strongly reduce illegal felling and illegal, and inefficient, charcoal making.

- 1.2.4 Bearing for an effective wood energy strategy

The conclusions from this study indicate that a balance condition between supply and demand of woody biomass for energy in 2020 can only be achieved if several (if not all) of the potential levers of improvement of the current production / consumption parameters are targeted. Such levers include:

1. Introduction of new energy sources (LPG, biogas, etc.)
2. Widespread use of improved stoves
3. Increase of the forest cover (plantations)
4. Use of modern carbonization techniques
5. Improvement of the forest productivity
6. Increase in the number of trees planted in the agricultural environment (agro-forestry)

In the Energy Sector Strategic Plan (ESSP) 2012-2017 (Ministry of Infrastructure, Draft 1, October 2012) only the first three levers listed above have been discussed, while their estimated impact potential on the balance between supply and demand of energy wood (see Table 6) only amounts to 11%, 22% and 15.5% respectively, when considered separately.

On the other hand, levers 4, 5 et 6 have not yet been clearly brought out and elaborated upon, although these aspects may have the highest impact (40%, 42% and 29% respectively) on maintaining the balance between supply and demand of energy wood.

When not taking into consideration the crucial role of the points of improvement 4, 5 and 6, any energy strategy seriously jeopardizes the future availability of wood energy resources. Yet energy wood will continue to be the most important source of energy in Rwanda for several more years to come, not only in quantitative terms, but also in terms of satisfaction of the primary needs of the most disadvantaged people.

Therefore, it is of the utmost importance that authorities in charge of energy :

- Become directly involved in the support of modern carbonization techniques (trials of new kiln models and techniques adapted to the context of the country, support to the organization/regulation of the production chains, etc.), which moreover have a very positive impact on the emission of greenhouse gases.
- Include in their programme the importance of developing a partnership with the MINIRENA and the MINAGRI on all aspects related to biomass energy.

MINIRENA and MINAGRI, as authorities in charge of forestry and agriculture, must develop strong synergies in order to ensure:

- the development of agro-forestry
- the improvement of forest productivity
- the organization of mixed cooperatives of charcoal makers and wood producers in order to ensure the implementation of management measures and thereby the sustainability of the production chains.

1.3 BASIC ELEMENTS OF A SMP FOR KIGALI/RWANDA AND OF A PROPOSED NATIONAL WOOD ENERGY STRATEGY TO 2020

The Forestry Policy of Rwanda, in the framework of Vision 2020, EDPRS, and other national policies, "aims at making the forestry sector one of the bedrocks for sustainable development, thriving, developed, managed and utilized for sustainable benefits to all segments of society and the environment" (MINIFOM 2010).

Indeed, wood energy sits at the very core of the Forestry Policy of Rwanda, given that woodfuels are by far the most important forestry products, and the main source of energy for Rwandese households in both rural and urban contexts.

We may here confidently state that **there cannot be sustainable forestry in Rwanda without sustainable wood energy production.**

But wood energy must not be seen as a threat to Rwanda forests. In fact, wood energy, and particularly so charcoal making, represents a primary source of income for an important fraction of rural farmers, right where income opportunities are more scarce and more needed.

In addition, and most important, the demand for wood and woodfuels induces farmers throughout the country to plant individual trees, woodlots and plantations in spite of the limited land available and competition with food crops. The last forest cover map (CGIS 2012) revealed a forest cover higher than expected[7], and it is reasonable to assume that the forest area is slightly increasing since most of the plantations are private and consistent planting is going-on in public lands as well (i.e. PAREF planting programme).

This planting regime is good news but it's not enough, considering the high and increasing demand for fuelwood and charcoal of the Country. As discussed in this report, the Country is living in a deficit condition (not as dramatic as previously feared), with a gap that is likely to grow to 2.1 million tons of woody biomass by 2020.

In order to support, on the basis of the knowledge currently available, the development of a Supply Master Plan for Kigali/Rwanda, the following sections review the situation of Kigali woodfuel demand in the national context and indicate a set of strategic interventions aiming at filling the gap by 2020 and thus making the sustainable supply of Kigali a reality.

1.3.1 The role of the woodfuels demand of Kigali in the national context

- Kigali (here intended as the urban fraction of the Kigali City Province) plays a special role in the Rwanda wood energy context. With only 8 % of the total population, Kigali's woodfuels consumption covers 20.7 % of the entire national woody biomass consumption and 60% of the national charcoal consumption in 2009 (Table 8). Moreover, Kigali's predominance tends to increase as effect of urbanization and the consequent shift from fuelwood to charcoal of new urban dwellers, which is only partially offset by the shift from charcoal to LPG or to other non-biomass fuels.

[7] The forest cover in 2009 (reference year of the CGIS map) was 22.8% of the national land area, including all protected areas (forested and non) and all non-protected tree formations. By adding the coverage of trees outside forests, the national 2009 tree cover increases to 24.4%, which is slightly higher than the value 23.5% expected in 2012 in the EDPRS. If we add the shrub formations of the Eastern Province, the total woody vegetation cover (including tree-and-shrub formations) increases further to 33.2%.

- According to the BAU scenario, between 2009 and 2020, the consumption of charcoal and fuelwood in Kigali will increase from 0.99 to 1.4 million tons (woody biomass equivalent).
- Assuming full-scale penetration of improved stoves, improved production efficiency of all consumed charcoal and strong promotion (and subsidies) of LPG in substitution of charcoal (AME scenario), the consumption of woodfuels in Kigali will be 0.77 million tons, which is almost half the amount consumed in the BAU scenario.

Table 8: Woodfuels consumption in Kigali in 2009 vis-à-vis the national context and 2020 scenarios

	2009 Tot Rwanda	**2009** Kigali		**2020 Kigali**	
			% of Rwanda total	2020 BAU scenario Kigali	2020 AME scenario Kigali
Population	10,432,894	839,088	*8.0*	1,249,983	1,249,983
% of households using primarily:					
Fuelwood (%)	Province values	16.1 %		10 %	5 %
Charcoal (%)	Province values	76.3 %		75 %	65 %
Other fuels (%)	Province values	7.6 %		15 %	30 %
Households consumption of:					
Fuelwood (kt od)	2,990	40	*1.4*	37	17
Charcoal (kt od)	211	124	*58.8*	181	148
Charcoal (kt od, wood equivalent)	1,437	845	*58.8*	1,238	672
Total HH woodfuels consumption (kt od wood equivalent)	**4,427**	**885**	***20.0***	**1,275**	**690**
Total **Commercial** consumption (kt od wood equivalent)	125	89	*70.9*	128	69
Total **Public sector** consumption (kt od wood equivalent)	67	15	*22.8*	18	9
Total **Industrial sector** consumption (kt od, wood equivalent)	112	0	*0.0*	0	0
Total Fuelwood - all sectors (kt od)	3,188	63	*2.0*	62	31
Total Charcoal - all sectors (kt of Charcoal)	226	136	*60.2*	200	162
Total Charcoal - all sectors (kt od, wood equivalent)	1,543	929	*60.2*	1,361	740
Construction wood (kt od)	69	3	*4.9*	3	3
Total consumption (kt od, wood equivalent)	**4,800**	**992**	***20.7***	**1,423**	**770.2**

1.3.2 Woodfuels supply sources of Kigali

Kigali has the most important woodfuels market in Rwanda and draws its supply from all parts of the Country. Since the overall supply/demand balance is negative (assuming medium productivity variant), there is no supply zone for Kigali's demand that can be considered entirely sustainable.

Nevertheless, there are Districts that present a higher production potential and that can be identified as the primary sources of Kigali markets. According to WISDOM analysis (medium productivity variant) there are 12 District with a positive supply/demand balance, as shown in Table 9. The annual sustainable production of charcoal in the 12 Districts is 107 thousand tons, while the consumption of Kigali is 136 thousand tons (124 kt HH sector; 12kt commercial, approximately. This means that at least 29 thousand tons (21 %) of the charcoal consumed is non sustainable. It is probable that good part of the non-sustainable charcoal is produced in the same districts. Indicatively, in Table 9 the non-sustainable charcoal fraction is distributed proportionally to Districts' wood resources. The most important supply Districts are Nyaruguru, Nyamagabe, Karongi and Nyamasheke, which account for some 84% of the supply, as more or less confirmed by charcoal transporters and Kigali market dealers (see Section 2.3.1.3).

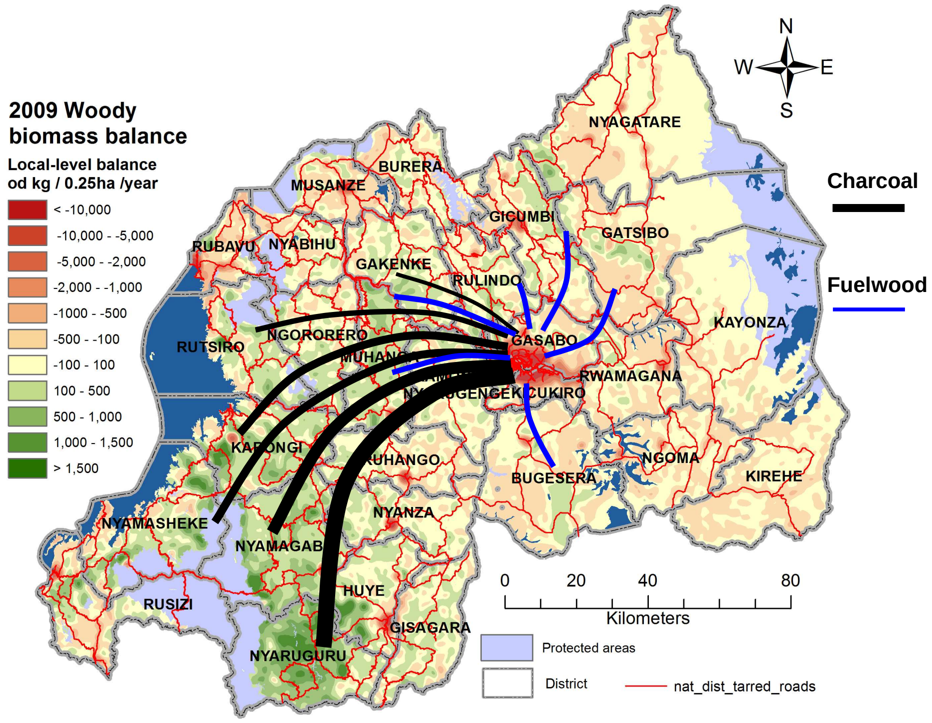
The quantity of fuelwood consumed in Kigali, 63 thousand tons, is far less important than charcoal. However, since we have already "assigned" all available District-level surpluses for charcoal production, the entire fuelwood used in Kigali must be accounted as non-sustainable. It is more difficult to identify the supply sources of this fuelwood since the chain is less formal and regular than for charcoal. Tentatively, the Districts of origin of fuelwood sold in Kigali are assumed to be the nearest ones to the city with more wood resources (or rather, a smaller deficit). Figure 2 provides an outline of the proveniences of the charcoal and, tentatively, of the fuelwood sold in Kigali.

Table 9: Probable Districts of provenance of the charcoal and fuelwood sold in Kigali in 2009. The distribution according to transporters and retailers vis-à-vis District-wise surplus conditions

	Supply/demand balance in 2009	Sustainable Charcoal "export" potential to Kigali	Probable non-sustainable charcoal production sold in Kigali	Probable sources of fuelwood sold in Kigali
	Woody biomass	Total Charcoal consumption in Kigali in 2009: 136 kt [a]		Fuelwood consumption in 2009: 63 kt od
"Surplus" Districts (decreasing surplus order)	kt od	kt of Charcoal [a]	kt of Charcoal [a]	kt of fuelwood (od)
NYARUGURU	278	41	11.0	
NYAMAGABE	165	24	6.5	
KARONGI	93	14	3.7	
NYAMASHEKE	80	12	3.2	
RUTSIRO	25	4	1.0	
GAKENKE	22	3	0.9	10
NGORORERO	21	3	0.8	
GISAGARA	11	2	0.4	
MUHANGA	11	2	0.4	10
RULINDO	9	1	0.4	10
KAMONYI	9	1	0.4	10
HUYE	6	1	0.2	
"Deficit" Districts (all other 18 Districts)	- 1600			22
Overall 2009 balance	**-870**			
Total production sold in Kigali		**107**	**29**	**63**

[a] Values are '000 tons of charcoal. Assuming traditional charring techniques, 1 ton of charcoal requires 6.8 tons of wood (oven dry weight).

Figure 2: Main proveniences of charcoal and fuelwood supplying Kigali market



1.3.3 Recommended District-level interventions aiming at sustainable wood energy by 2020

The quantification of the needs of Kigali users for charcoal and fuelwood and the identification of the probable sources of supply of Kigali woodfuels market are essential for planning and for focusing the attention of planners and administrators on this important woodfuel chain.

However, since the Country as a whole has a sizeable deficit, there is no action that can guarantee the sustainable supply of Kigali without keeping into consideration the national-level supply/demand balance.

Therefore, a pre-requisite for the envisaged Woodfuels Supply Master Plan of Kigali is necessarily the national wood energy strategy that has the scope of filling the supply/demand gap and of making wood energy in Rwanda sustainable between now and 2020. In practice, the solution for Kigali is simply part of the solution for Rwanda.

As discussed in the previous section, there are several lines of interventions aiming at the reducing the demand and at increasing the sustainable supply that must be combined, as ingredients of a recipe, in order to fill in the national woodfuel deficit. Table 7 of Section 1.2.2 above describes what appears a sound and well balance "blending" of the various interventions, but several other combinations are possible and we encourage all stakeholders to discuss the pros and cons of each option[8].

The interventions to be implemented according to the above mentioned strategy, may be separated into two main groups:

Interventions targeting rural and urban households and farmers and requiring a very diffuse action:

- **Dissemination of improved stoves**: Increase penetration of 20 %.
- **Agro-forestry:** Promote tree planting in farmlands in order to achieve a 2% increase of tree cover outside forest areas.

[8] For a more detailed discussion of the main possible interventions and on the impact that each one could have towards the filling of 2020 woodfuel gap, see Section 2.4 in the following chapter.

Interventions of more specific forestry character:

- **Better management of existing forests:** Improved management over 150,000 ha of private and public plantations with priority to charcoal production Districts.
- **Promotion of efficient charcoal making**: Improve charring techniques on 75% of the production of the main 4 charcoal producing Districts.
- **Creation of new plantations:** Planting of approx. 30 thousand ha with priority to Eastern and Northern provinces and to steep slope areas.

These interventions, which are to be implemented between now and 2020 in order to fill in the supply/demand deficit expected for that year are hereafter described and quantified at District level.

1.3.3.1 Interventions targeting households and farmers

These interventions aim at increasing improved stoves penetration and increasing tree cover in rural areas.

Dissemination of improved stoves. Increase of 20% the penetration of improved stoves in rural and urban areas.

The dissemination of improved stoves has a long history in Rwanda and the current penetration is regarded as being quite high, ranging from 50 to 70 %, depending on the sources consulted. The adoption of improved stoves in 20% of rural and urban households is estimated to save approximately 318 kt of woody biomass (od), which represents some 15 % of the 2.1 million tons gap expected by 2020.

The number of stoves to be distributed is close to 450 thousand units, over the period 2014 and 2020, with a District-wise distribution as proposed in Table 10. Considering 7 years of implementation, the number of stoves to be annually distributed in each District ranges between 1,600 and 3,000 units, depending on the number of households in that District.

From a pure wood-saving perspective, the benefit of a strong stove dissemination program such as the one proposed here does not appear very substantial. However, due consideration must be given to the important improved air and health conditions that these stoves bring into poor households. Moreover, some of the improved stoves currently in use appear only marginally more efficient than the customary three-stone system and therefore there might be significant benefit for the households, as well as for the woodfuels balance, in re-launching stove substitution programs with more efficient stove models. In addition, this intervention should be combined with the National Biogas Program of EWSA, promoting substitution of old woodfuel stoves with biogas systems wherever appropriate.

Agro-forestry (increase of tree cover in farmlands)

The role of individual farm trees and very small woodlots in providing woody biomass for energy and other uses is important, although their quantitative contribution is not yet well defined. The current contribution by trees and shrubs in farmlands is conservatively estimated at 611 thousand tons per year. The increase of tree cover of adequate species would considerably contribute to the energy need of rural households as well as providing small income in case of needs, as farmers know very well.

An additional tree cover of 2 % of the farm area is estimated to produce approximately 413 kt of woody biomass annually and thus contribute to fill in some 20 % of the 2.1 million tons gap expected by 2020. To achieve such target, over 20 million seedlings must be distributed and planted by farmers throughout the Country by 2020. This means amounts of seedlings to be produced, distributed and planted annually in each District ranging between 16 and 185 thousand, depending on the available non-forest areas. The proposed District-wise distribution of seedlings and tree planting shown in Table 10 is proportional to the farming areas and aims at a uniform increase of tree cover. An alternative approach may be to increase this agro-forestry program in steep slope areas of Western and Northern Provinces in order to combine protective and productive functions in areas particularly subject to soil erosion.

The interventions described above imply systematic and widespread action through Rwanda for the period from now to 2020. Given the typology of interventions and their strong rural character (except for the part concerning improved stoves dissemination in urban households) it is strongly recommended to combine these two actions and to develop/strengthen the synergies with the Regional Project "Sustainable Energy Production through Woodlots and Agroforestry in the Albertine Rift" implemented by the International Fertilizer Development Centre (SEW/IFDC).

Table 10. District-wise interventions on improved stoves and agro-forestry: Number of improved stoves to be distributed and adopted by rural and urban households by 2020; Number of seedlings to be distributed and planted by farmers by 2020.

		Dissemination of improved stoves (increase penetration of 20%)		**Agro-forestry** (increase of tree cover of 2%)	
		2009 Households	Number of improved stoves to be distributed by 2020	Non-forest area	Seedlings to be distributed & planted in rural areas by 2020
Province	District	('000 units)	(units)	('000ha)	('000 units)
Kigali City	**NYARUGENGE**	57.0	11,300	8.9	112
	GASABO	99.1	19,800	29.1	364
	KICUKIRO	59.6	11,900	10.4	130
Southern	**NYANZA**	67.6	13,500	59.5	744
	GISAGARA	77.8	15,500	59.6	745
	NYARUGURU	64.7	12,900	51.9	649
	HUYE	68.7	13,700	46.1	577
	NYAMAGABE	70.8	14,100	60.0	750
	RUHANGO	66.5	13,300	55.7	696
	MUHANGA	61.0	12,100	50.4	630
	KAMONYI	68.3	13,600	57.9	724
Western	**KARONGI**	73.7	14,700	58.1	726
	RUTSIRO	68.3	13,600	42.2	527
	RUBAVU	85.5	17,000	27.8	348
	NYABIHU	69.7	13,900	34.5	431
	NGORORERO	76.4	15,200	51.6	645
	RUSIZI	79.6	15,900	46.1	577
	NYAMASHEKE	78.4	15,600	51.6	645
Northern	**RULINDO**	62.8	12,500	44.7	559
	GAKENKE	76.7	15,300	55.4	692
	MUSANZE	85.2	17,000	34.6	433
	BURERA	74.2	14,800	49.4	617
	GICUMBI	114.1	22,800	65.3	816
Eastern	**RWAMAGANA**	64.1	12,800	59.7	746
	NYAGATARE	86.9	17,300	103.8	1,297
	GATSIBO	103.6	20,700	76.6	958
	KAYONZA	72.0	14,300	67.5	844
	KIREHE	71.1	14,200	89.1	1,114
	NGOMA	71.6	14,300	73.5	919
	BUGESERA	82.0	16,300	98.3	1,229
		2,257	**449,900**	**1,619**	**20,243**
Provincial	**summary**				
	KIGALI CITY	216	43,000	48	605
	SOUTHERN	545	108,700	441	5,515
	WESTERN	532	105,900	312	3,899
	NORTHERN	413	82,400	249	3,117
	EASTERN	551	109,900	569	7,107
Total	**RWANDA**	**2,257**	**449,900**	**1,619**	**20,243**

1.3.3.2 Interventions of more specific forestry character

These interventions aim at improving forest productivity, producing charcoal more efficiently and increasing plantation area in priority areas.

Better management of existing forests.

The management of forest resources in Rwanda has a great potential because the ecological characteristics are in general suitable for forest plantations, because private landowners recognize the economic value of plantations and planting trees has become part of farm management practices, and because forest management has been virtually absent, so far. A lot can be done in forest management and most actions should be in support of plantation forestry in private and public lands. As in the case of charcoal making, the action must be oriented towards enabling framework conditions, such as governance, taxation and regulation, as well as towards silvicultural support.

It must be emphasized that a detailed inventory of forest resources is a fundamental pre-requisite to improved forest management in Rwanda.

The increase in productivity of existing plantation area, here considered, would be the end result of a wide series of silvicultural actions that include, among others: farmers access to optimal genetic resources and support in the selection of suitable species; training on good nursery, planting and maintenance practices; farmers access to fertilizers needed to integrate soil nutrients; clear prescriptions and training on felling practices; optimized rotation systems oriented to the production of the required wood assortments; etc. Along with increased productivity and sustainability, improved forest management will consolidate and increase income generation and employment in rural areas.

It is estimated that improved management carried out over half of the existing plantations (including a 10 % increase in plantation area between 2009 and 2020) will increase productivity of approximately 440 thousand tons, or 20 % of the 2020 gap. This intervention should concentrate with priority on charcoal production Districts, covering 90% of the planted areas, as shown in Table 11.

It is unlikely that this increment of production be reached entirely by 2020, as 7 years is a too short timeframe in forestry, but it shows the great potential of good forest management and helps to visualize the challenge of forestry planning in Rwanda.

Promotion of efficient charcoal making.

Raising the yield of charcoal production from the current 12% to 18% is certainly an ambitious target, but from a technical point of view this seems to be realistic (Kammen and Lew, 1995; BEST; Murererehe, personal communication). The issue, however, is that the reason for the current poor performance of charcoal yields is in good part due to the rigidity and cost of the authorization process, which induce many wood owners to opt for clandestine tree cutting and charcoal production, or simply to act too fast, as discussed in Section 1.2.3 above. Hence, the promotion of efficient charcoal making techniques must proceed hand-in-hand with the setting of friendly regulations and permit systems favoring sustainable charcoal production and encouraging adoption of modern techniques.

This intervention should focus on 75% of the charcoal production in Nyaruguru, Nyamagabe, Nyamasheke and Karongi Districts. The scope will be to create favorable taxation and permit system rewarding efficiency and sustainability; to promote cooperatives of producers and increase charcoal yields through more efficient charring techniques. This intervention aims at improving charcoal making in the main charcoal Districts mentioned above reaching the production of "improved" charcoal for approximately 120 thousand tons by 2020, as shown in Table 11, with an estimated saving of 630 thousand tons of wood (od), or 30% of the gap.

The two interventions are proposed to operate with priority over the Districts with high forestry potential. This combination and coordination of the two actions (management and charcoal production) over the same territories will increase the efficiency and consolidate the impact.

Table 11. District-wise interventions on efficient charcoal making and on forest management: Tons of charcoal to be annually produced through efficient techniques in 2020; Hectares of public and private plantations to be covered by management plans by 2020.

		More efficient charcoal making		Better management of existing forests	
		Charcoal production proportional to fuelwood surplus 2009 (tentative)	Charcoal to be made through efficient systems (yield of 18%)	2009 plantation area	Plantations to be put under forest management plans (90% of selected District's planted area)
Province	District	kt of charcoal	kt of Ch to be improved	Ha of plantations	Ha of plantations
Kigali City	**NYARUGENGE**	0.0		2,448	
	GASABO	0.7		6,763	
	KICUKIRO	0.0		1,059	
Southern	**NYANZA**	1.4		7,130	
	GISAGARA	5.2		8,154	7,300
	NYARUGURU	65.1	48.9	26,840	24,100
	HUYE	10.5		11,496	
	NYAMAGABE	42.7	32.0	28,319	25,400
	RUHANGO	0.0		6,851	
	MUHANGA	12.9		13,594	12,200
	KAMONYI	3.6		7,603	6,800
Western	**KARONGI**	28.4	21.3	19,288	17,300
	RUTSIRO	10.5		9,727	8,700
	RUBAVU	0.0		2,998	
	NYABIHU	0.4		6,898	
	NGORORERO	9.7		10,814	9,700
	RUSIZI	0.7		8,294	
	NYAMASHEKE	23.8	17.8	17,877	16,000
Northern	**RULINDO**	3.6		12,005	10,800
	GAKENKE	6.9		14,877	13,300
	MUSANZE	0.0		5,101	
	BURERA	0.0		6,272	
	GICUMBI	0.0		16,451	
Eastern	**RWAMAGANA**	0.0		5,354	
	NYAGATARE	0.0		7,364	
	GATSIBO	0.0		9,791	
	KAYONZA	0.0		4,453	
	KIREHE	0.0		1,513	
	NGOMA	0.0		3,926	
	BUGESERA	0.0		3,540	
		226	**120**	**286,797**	**151,600**
Provincial	**summary**				
	KIGALI CITY	1		10,270	
	SOUTHERN	142	81	109,986	75,800
	WESTERN	73	39	75,895	51,700
	NORTHERN	10		54,706	24,100
	EASTERN	0		35,940	
Total	**RWANDA**	**226**	**120**	**286,797**	**151,600**

Creation of new plantations.

Creation of new plantations to achieve a national tree/forest cover of 30% is envisioned in forestry policy papers, with particular attention to steep slopes in order to combine protective and productive functions.

However, with high rural population density and considering the agricultural basis of its economy, Rwanda is an intensely farmed country and finding suitable areas for new forest plantations is no simple matter, even on areas apparently unsuitable for farming.

The creation of new **plantations on steep slope areas** appears rather complex because steep slopes are often occupied by intensive terraced farming, as discussed in Annex 4. The land area with slope above 55% that is not yet under forest amounts to approximately 52 thousand hectares, but it's difficult to say what part of this area may constitute a suitable target for conventional planting. A systematic review of the land use and ownership status of steep areas is a necessary pre-requisite for the identification of suitable planting sites.

The creation of **conventional plantations** is considered more feasible and necessary in the Eastern Province of the Country where land use is less intensive and there is a marked deficit of fuelwood for local consumption. The deficit is quite evident in good part of the Northern Province, although finding suitable land for new plantations in this Province may prove more difficult.

For the above reasons, in this proposed set of interventions, we estimate feasible to identify and plant only 5,000 ha of new plantations on areas with slope greater than 55%, located in the Northern, Southern and Western Provinces, and some 25,000 ha of new plantations in the Northern and Eastern Provinces, as shown in Table 12.

A District-wise overview of the proposed interventions is presented in Table 13. From this summary table is possible to see at a glance Provinces and Districts where forestry and wood energy actions are to be considered prioritary in the perspective as set forth by the proposed "blending" of interventions.

Other combinations of interventions are possible, reducing the demand rather than increasing the supply, or vice versa. This could be done at national or at District level, by increasing the emphasis on one type of intervention and decreasing another one (i.e. more agro-forestry and less conventional planting; more charring improvements and less improved stoves; etc.). What must be kept in mind in any case is the possible impact at national level and the goal to achieve wood energy sustainability by 2020.

To be noted that these actions must be coupled with another fundamental component of the strategy, which is the regulatory frame that need to be reviewed at national and at District level in order to rationalize and reinforce the forestry and wood energy sector, as discussed in Section 1.2.3.

In addition, it is also recommended to encourage landowners to organize themselves in cooperatives, so that they may reduce the costs and increase the quality and quantity of wood production and exert a stronger influence on the price of wood products.

Table 12. District-wise creation of new plantations: Hectares of public and private plantations to be created in woodfuels deficit areas and on steep slope areas by 2020.

				Creation of new plantations in deficit Districts	Creation of new plantations on steep slopes
		Balance 2009 Medium prod. variance	2009 plantation area	25,000 ha of plantations to be created in North & East Provinces [a]	5,000 ha of plantations to be created in South, West, North Provinces [b]
Province	District	kt od	Ha	Ha	Ha
Kigali City	**NYARUGENGE**	-296.8	2,448		
	GASABO	-406.2	6,763		
	KICUKIRO	-310.7	1,059		
Southern	**NYANZA**	-18.4	7,130		21
	GISAGARA	11.2	8,154		14
	NYARUGURU	278.4	26,840		97
	HUYE	6.2	11,496		17
	NYAMAGABE	164.7	28,319		283
	RUHANGO	-30.6	6,851		14
	MUHANGA	11.0	13,594		306
	KAMONYI	9.0	7,603		40
Western	**KARONGI**	93.0	19,288		323
	RUTSIRO	25.5	9,727		273
	RUBAVU	-91.1	2,998		65
	NYABIHU	-16.6	6,898		363
	NGORORERO	20.6	10,814		483
	RUSIZI	-29.0	8,294		366
	NYAMASHEKE	79.5	17,877		302
Northern	**RULINDO**	9.1	12,005	1,366	370
	GAKENKE	22.2	14,877	1,693	682
	MUSANZE	-64.6	5,101	1,058	106
	BURERA	-19.9	6,272	1,509	487
	GICUMBI	-26.5	16,451	1,996	387
Eastern	**RWAMAGANA**	-43.5	5,354	1,824	
	NYAGATARE	-35.6	7,364	3,172	
	GATSIBO	-38.8	9,791	2,342	
	KAYONZA	-31.4	4,453	2,064	
	KIREHE	-51.4	1,513	2,723	
	NGOMA	-46.7	3,926	2,248	
	BUGESERA	-42.1	3,540	3,006	
		-870	**286,797**	**25,000**	**5,000**
Provincial	**summary**				
	KIGALI CITY	-1,014	10,270	0	0
	SOUTHERN	431	109,986	0	792
	WESTERN	82	75,895	0	2,175
	NORTHERN	-80	54,706	7,621	2,033
	EASTERN	-290	35,940	17,379	0
Total	**RWANDA**	**-870**	**286,797**	**25,000**	**5,000**

[a] 25,000 ha of plantation in Northern and Eastern Provinces proportionally to the accessible (non protected) non-forest land.

[b] 5,000 ha of plantations in Southern, Western and Northern Provinces proportionally to the accessible (non protected) non-forest land with slope >55%.

Table 13. Summary of District-wise interventions to be implemented by 2020 in order to fill in the woodfuel gap at national level.

Province	District	Number of improved stoves to be distributed by 2020 (units)	Seedlings to be distributed & planted in rural areas by 2020 ('000 units)	Charcoal to be made through efficient systems (kt of Ch to be improved)	Plantations to be put under forest management plans (Ha of plantations)	Plantations to be created in deficit areas (Ha)	Plantations to be created on steep slopes (Ha)
Kigali City	**NYARUGENGE**	11,300	112				
	GASABO	19,800	364				
	KICUKIRO	11,900	130				
Southern	**NYANZA**	13,500	744				21
	GISAGARA	15,500	745		7,300		14
	NYARUGURU	12,900	649	48.9	24,100		97
	HUYE	13,700	577				17
	NYAMAGABE	14,100	750	32.0	25,400		283
	RUHANGO	13,300	696				14
	MUHANGA	12,100	630		12,200		306
	KAMONYI	13,600	724		6,800		40
Western	**KARONGI**	14,700	726	21.3	17,300		323
	RUTSIRO	13,600	527		8,700		273
	RUBAVU	17,000	348				65
	NYABIHU	13,900	431				363
	NGORORERO	15,200	645		9,700		483
	RUSIZI	15,900	577				366
	NYAMASHEKE	15,600	645	17.8	16,000		302
Northern	**RULINDO**	12,500	559		10,800	1,366	370
	GAKENKE	15,300	692		13,300	1,693	682
	MUSANZE	17,000	433			1,058	106
	BURERA	14,800	617			1,509	487
	GICUMBI	22,800	816			1,996	387
Eastern	**RWAMAGANA**	12,800	746			1,824	
	NYAGATARE	17,300	1,297			3,172	
	GATSIBO	20,700	958			2,342	
	KAYONZA	14,300	844			2,064	
	KIREHE	14,200	1,114			2,723	
	NGOMA	14,300	919			2,248	
	BUGESERA	16,300	1,229			3,006	
Total	**RWANDA**	**449,900**	**20,243**	**120**	**151,600**	**25,000**	**5,000**

2. UPDATE AND UPGRADE OF WISDOM RWANDA

This section describes the rationale and key features of the methodology termed "Woodfuels[9] Integrated Supply/Demand Overview Mapping (WISDOM)", a diagnostic and planning tool in support to wood energy planning and policy formulation developed by FAO (Drigo et al. 2002; FAO 2003), and provides an overview of the analytical steps and data sources used in the updated version of WISDOM Rwanda.

WISDOM was implemented for Rwanda in 2009-2010 by FAO/NAFA (Drigo and Nzabanita, FAO 2011) and this report documents the update and upgrade of the WISDOM Rwanda analysis in support to the formulation of a Woodfuel Supply Master Plan for Kigali.

2.0.1 Analytical steps of WISDOM methodology

The WISDOM methodology may be divided into two sequential phases/contexts of analysis:

1 - WISDOM Base. This phase includes the analysis over the entire territory of the study area.

2 - Woodshed[10] analysis. This phase of analysis uses the result of the WISDOM Base to delineate the sustainable supply zone of selected consumption sites such as urban centers or existing/planned biomass plants.

In order to be applied, the *woodshed* analysis requires that the supply zone be only a portion of the entire country area. In case of Rwanda, however, it appears that the demand for woodfuels is greater than the sustainable supply potential, which means that the supply zone of Kigali is the whole country. Therefore the woodshed analysis is not applicable in this case.

The specific steps of analysis are summarized below while a graphic overview is shown in Figure 3. The detailed description of the data used and analysis conducted in each step is given in the following Sections.

The application of the standard WISDOM analysis producing supply and demand balance mapping at the local level involves five main steps (FAO, 2003b).

1. Definition of the minimum administrative *spatial* unit of analysis.
2. Development of the *demand* module.
3. Development of the *supply* module.
4. Development of the *integration* module.
5. Selection of the *priority* areas or woodfuel "hot spots" under different scenarios.

The flowcharts of Figures 4 and 5 provide an overview of the main "ingredients" and of the sequence of actions undertaken in the development of the Demand and Supply Modules, highlighting the new data sources used to update and upgrade the analysis.

[9] The terms and concepts used in this paper make reference to the definitions and terminology provided in the paper "Unified Bioenergy Terminology" (UBET) and, concerning woodfuel flows, to those described in the paper "A guide for woodfuel surveys".

[10] The term "woodshed" is a neologism inspired by the familiar geographic concept of *water*shed. It is used to indicate the portion of the territory necessary to supply on a sustainable basis the woody biomass needed by a specific consumption site (existing or hypothetical).

Figure 3: WISDOM analytical steps. WISDOM Base (steps 1 to 5) and Woodshed analysis (steps 6 and 7).

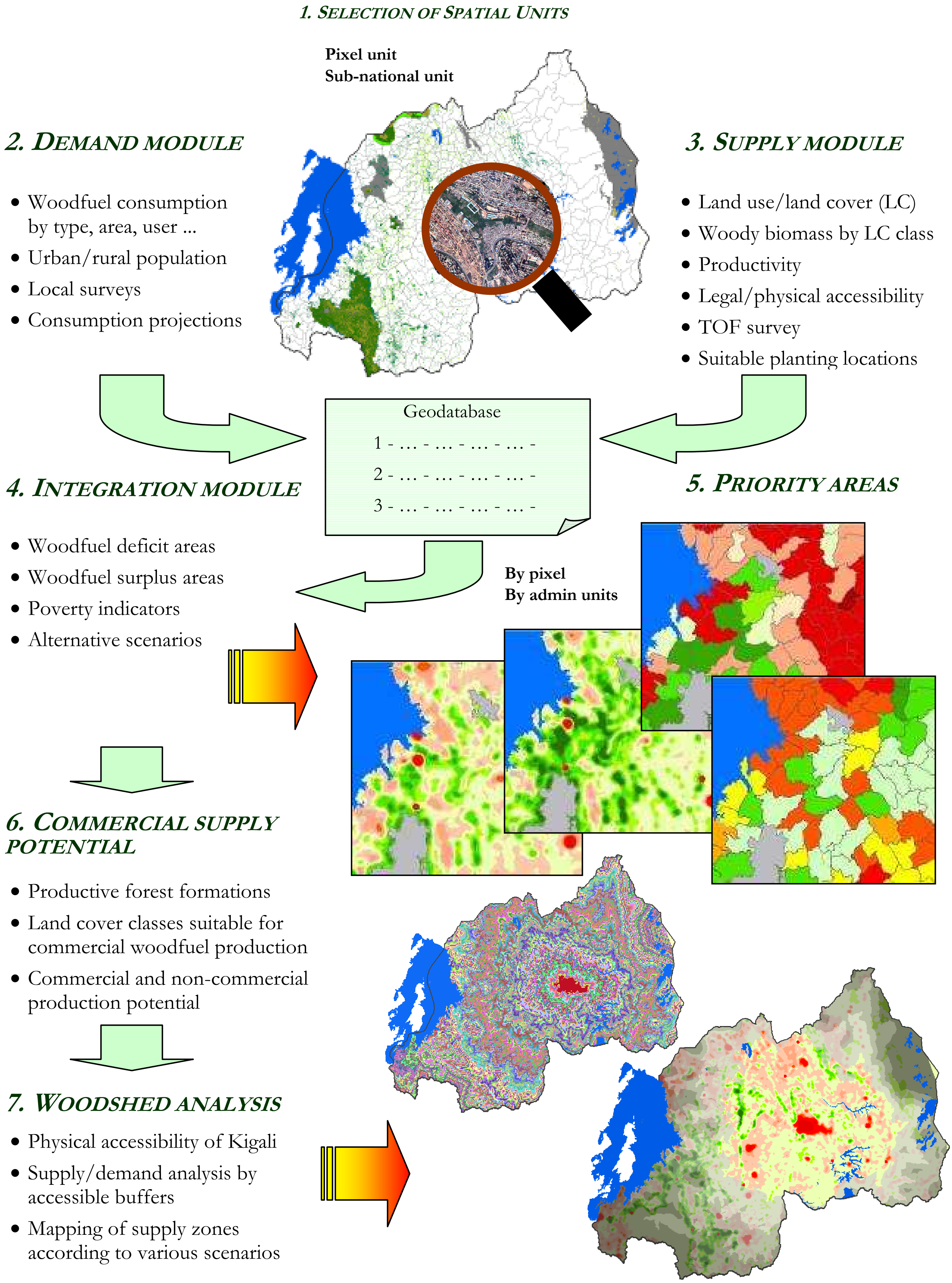
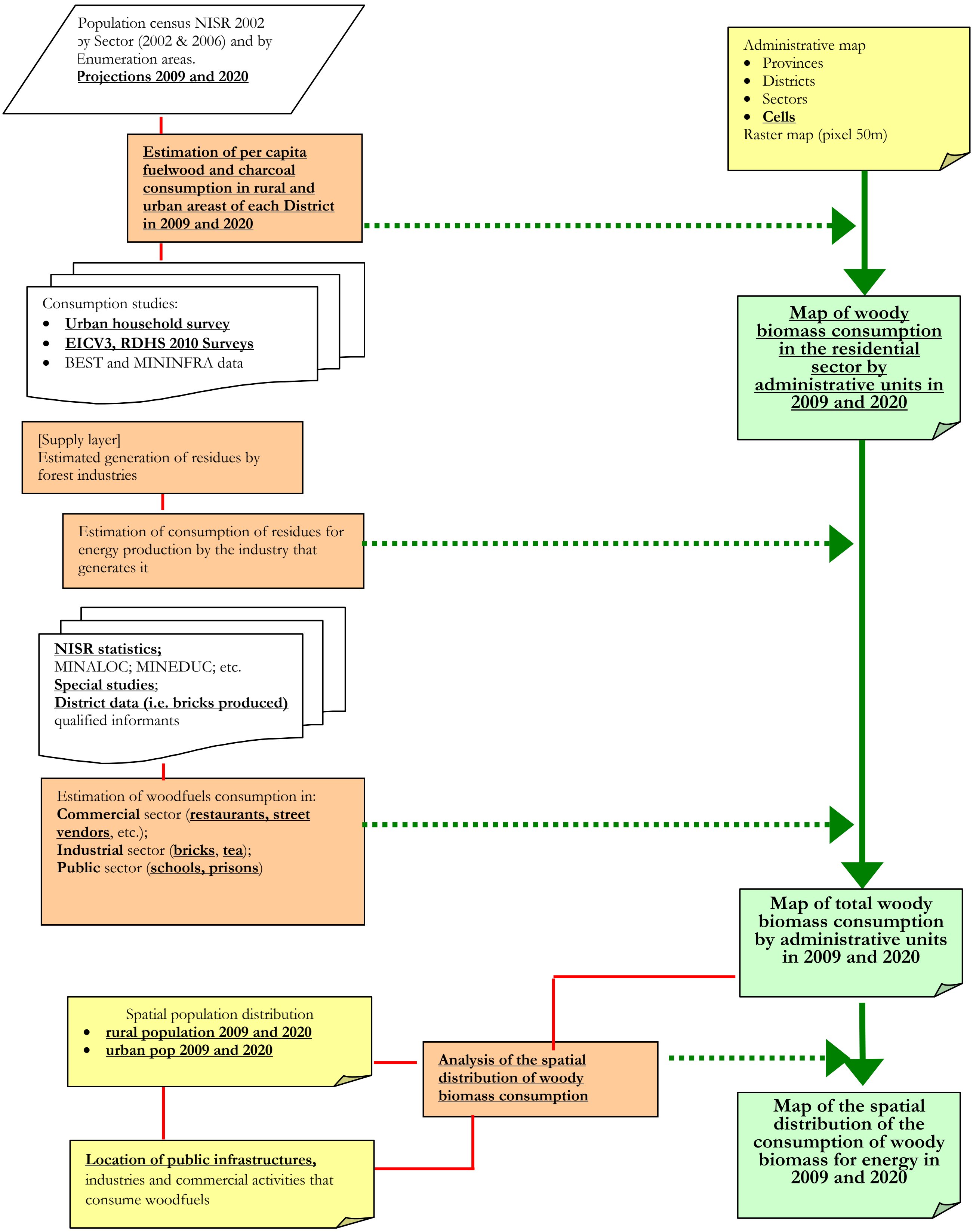
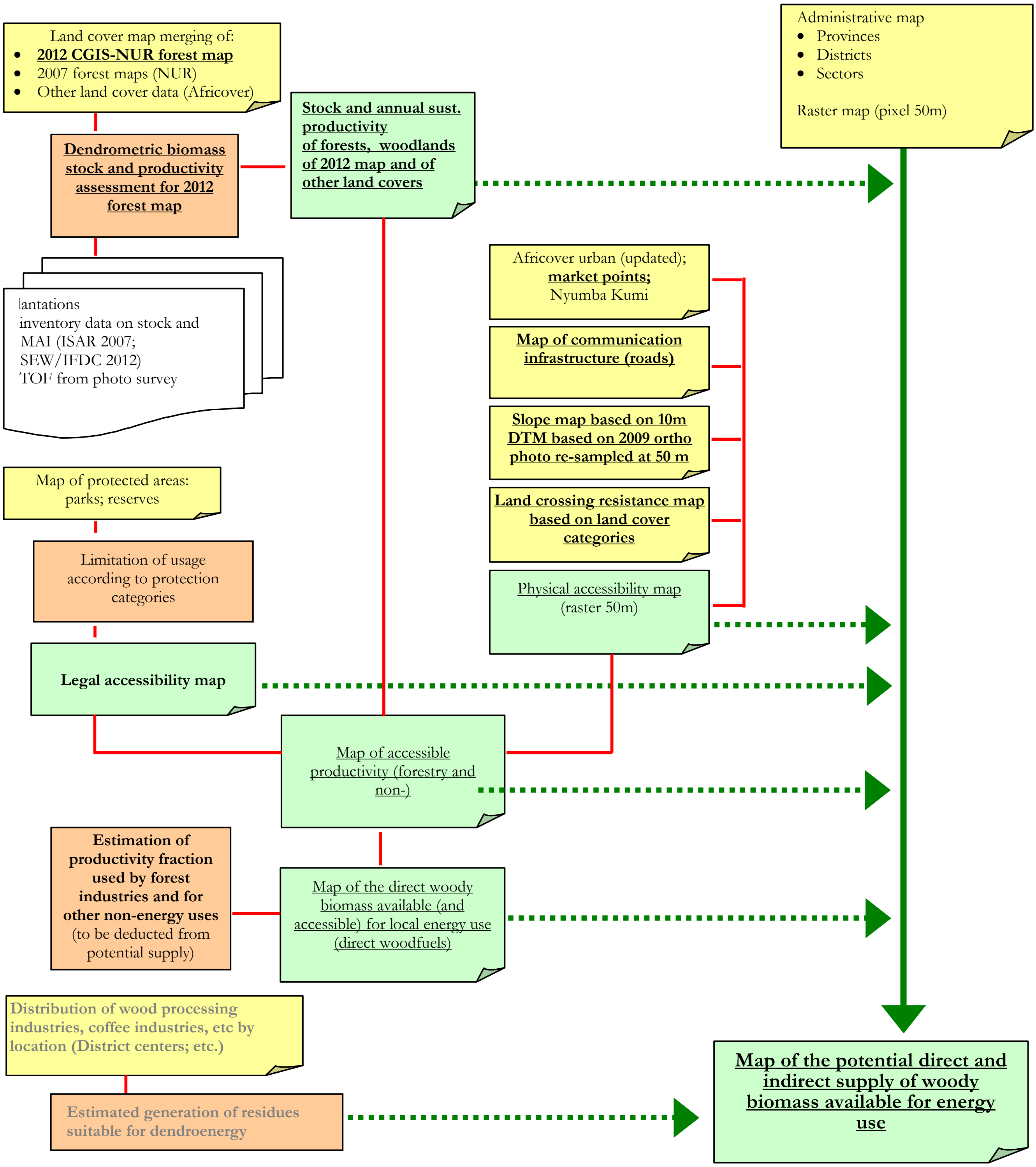


Figure 4: Upgrade and update of WISDOM Rwanda: Demand Module. Flowchart of main analytical steps.



Note: Main data sources and analytical steps used to update and upgrade the analysis are bolded and underlined

Figure 5: Upgrade and update of WISDOM Rwanda: Supply Module. Flowchart of main analytical steps



Note: Main data sources and analytical steps used to update and upgrade the analysis are bolded and underlined. The items for which no data could be obtained are in grey.

2.0.2 Transfer of WISDOM Geo-database and basic GIS training

The updated and upgraded WISDOM Geo-database was transferred to the computer of the RNRA Forest professional upon completion of the analysis. The list of map layers that compose the geo-database is provided in Annex 6, along with a short description of the sources and processing steps undertaken for their production.

In order to operate on WISDOM map layers, the ESRI ArcGIS 9.1.3 software has been installed on the same computer. The software license used is the one that FAO had provided to the former NAFA (National Forests Authority) which has become Department of Forests and Nature Conservation (DFNC) in the Rwanda Natural Resources Authority (RNRA). Through the GIS software the data (vector and raster format) can be visualized, analyzed at different administrative level for information to help reporting and decision making. Table 14 provides an overview of the levels of interaction that can be developed and the corresponding GIS skills required.

Table 14: Levels of interaction with the WISDOM datasets

Level of interactions	Description of the possible applications	Required GIS skills
Elementary Level: Extraction of statistics by sub-national units	Use administrative units boundaries to extract statistics from raster datasets containing spatial statistics of supply and demand	Basic skills of GIS and geoprocessing tools such as Zonal Statistics
Medium Level: Production of thematic maps for selected locations or sub-national units	With the results of the extracted statistics, select the location or sub-national unit by the required techniques (select by attribute, select by location, for vector layer, or masking the selected unit in case of raster); layout map preparation	Moderate skills in GIS and geoprocessing tools
Advanced Level: Change of demand or supply parameters and re-running of WISDOM analysis	Change the parameters settings of the supply or demand according to new information; re-run the geoprocessing tools or models to process new demand or supply raster datasets	Advanced skills of WISDOM concepts (Expert), advanced knowledge of GIS and geoprocessing

In order to facilitate the understanding of the data, the consultation and the elementary handling of WISDOM layers, basic training was provided to the DFNC counterpart on GIS principles and data handling tools. The training focused on how to extract statistics concerning whatever information by administrative unit and other simple operations and covered the following subjects:

- Introduction to GIS: manipulation geographic data (vector and raster datasets): Using ArcCatalog and ArcMap, Exploring a map, Editing in ArcMap, Querying data.
- WISDOM geo-database handling: Retrieving information available in different raster datasets: Converting vector into raster, working with raster datasets, zonal statistics.
- Producing maps and embedding generated maps in documents of different formats (such as Word, PowerPoint)

The training program is detailed in the project document "Introduction to GIS and Woodfuel Integrated Supply/Demand Overview Mapping (WISDOM) Concepts. Training manual for the (RNRA/DFNC) Professionals" by V. Nzabanita, May 2012; 50 pages), which is provided separately.

2.1 DEMAND MODULE

2.1.1 Residential sector consumption 2009 and 2020 scenarios

Consumption of woodfuels in the residential sector, which is the most important element of the Demand Module, was mapped with reference to 2002 (census year), 2009 and 2020 (NISR, 2009). The analysis included the following steps:

1. Spatial distribution of the urban and rural population was done through the following steps:
   - i. Delineation of urban areas. The source information used included Africover Rwanda dataset complemented by Google Earth interpretation and RNRA Land cover map (orthophoto-based) for missing/outdated city boundaries.
   - ii. Use of the georeferenced "Nyumba Kumi" points[11] as proxy for the spatial distribution of rural population within census administrative units (2002 Sectors layout). The original dataset was integrated by the National GIS Consultant for the sub-national units for which the Nyumba Kumi points were not available. The final map of rural data points includes 104 320 points, which supports a very detailed spatial distribution of the Country's rural population.
   - iii. Development of a simple algorithm relating 2002 official census data by Sector (2002 layout) with the spatial features such as urban pixels and rural pixels. In the absence of data on population distribution dynamics, the populations projected to 2009 and to 2020 (NISR 2009) were distributed using the same spatial feature of 2002, changing in each case the number of persons associated to the pixels.
   - iv. Creation of the distribution maps of rural and urban population in 2002, 2009 and 2020 as crude pixels maps.
   - v. Creation of smoothed interpolation maps for 2002, 2009 and 2020 based on spatial analysis whereby the pixel values in the new map are determined by the average values of the pixels in the surrounding 1.5 km in the source map. The smoothed maps provide a better visualization of the population density (Figure 6).
2. Estimation of per capita consumption in rural and urban areas and by administrative unit, based on available reference data.
   - i. The per-capita and per-household consumption rates in rural and in urban areas for the year 2009 were based primarily on the urban households' survey conducted by the project [12].

For the consumption in 2020, two scenarios were considered:

- a business as usual (BAU) scenario reflecting the present situation, applying the same per capita consumption values of 2009 (to the 2020 population) as well as trend observed in the penetration of alternative fuels, such as LPG, as an effect of economic growth.
- an "ameliorated" (AME) scenario assuming:
  - (i) a 30 % increase in the penetration of improved fuelwood stoves (from the current 50-70% to 80-100 %, tentatively),
  - (ii) an increase of improved charcoal stoves: in Kigali, from the current 77% to 100% and a 30% increased penetration of improved charcoal stoves in other urban areas (from the current 60-70% to 90-100%).

[11] The map giving the lat/long position of the household of the chief of the Nyumba Kumi that group the surrounding 10/15 households.

[12] A survey of woodfuel consumption was recently conducted by EWSA but the final results were not yet available at the time of Demand Module analysis. The results of the EWSA survey, now available, indicate a total woodfuel consumption of 4.75 million od tons, wood equivalent, which matches very closely the consumption estimated in this study of 4.8 million od tons.

- (iii) a higher efficiency in charcoal production from the current 12%[13] to 18%, as a result of a series of actions aiming at rationalizing and improving the efficiency of charcoal making between now and 2020, and
- (iv) a higher, but realistic, penetration of LPG in the energy mix of urban households.

Per capita consumption rates are shown in Table 15. The results of the urban consumption survey provided evidence of different consumption rates between Kigali, the Southern province and the other provinces. The difference appeared particularly evident for urban charcoal consumption, as shown in Table 10.

Table 15: Reference per capita fuelwood and charcoal consumption values used to estimate the consumption in 2009 and in 2020 according to the business-as-usual scenario (BAU) and to the ameliorated scenario (AME).

BAU Scenario

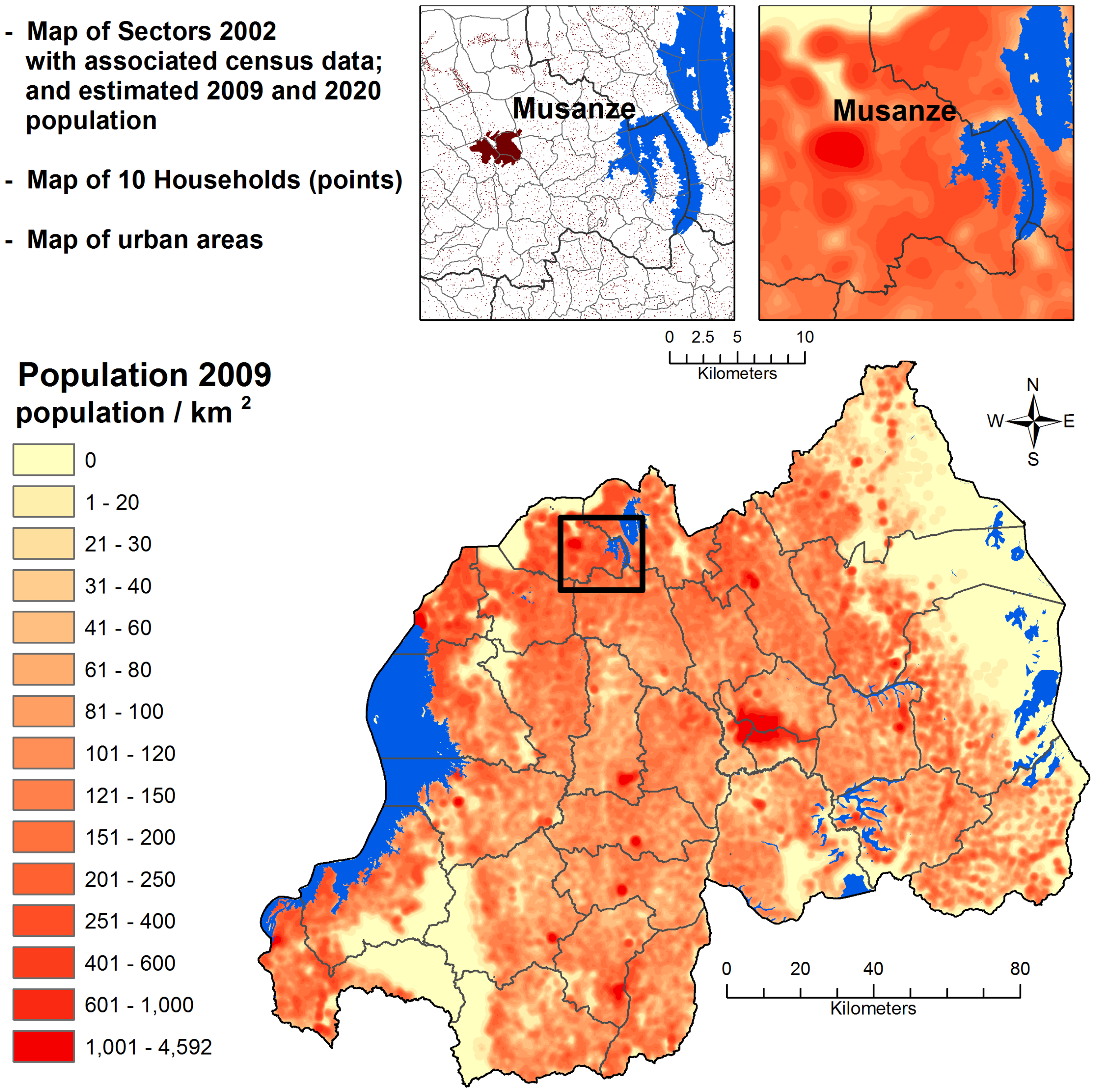
	Rural areas				**Urban areas**			
	Fuelwood		**Charcoal**		**Fuelwood**		**Charcoal**	
Improved stoves penetration	50-60%		60-70%		50-60%		77% Kigali	
Charcoal yields			12%				12%	
	Per-capita consumption by fuelwood users		Per-capita consumption by charcoal users		Per-capita consumption by fuelwood users		Per-capita consumption by charcoal users	
Province	Air-dry kg /year	Oven-dry kg /year	kg of charcoal /year	wood equivalent (kg od/year)	Air-dry kg /year	Oven-dry kg /year	kg of charcoal /year	wood equivalent (kg od/year)
Kigali					366	299	194	1320
South	409	335	175	1196	378	310	252	1720
Other					422	345	121	822

AME Scenario

	Rural areas				**Urban areas**			
	Fuelwood		**Charcoal**		**Fuelwood**		**Charcoal**	
Improved stoves penetration	80-90%		90-100%		80-90%		100%	
Charcoal yields			18%				18%	
	Per-capita consumption by fuelwood users		Per-capita consumption by charcoal users		Per-capita consumption by fuelwood users		Per-capita consumption by charcoal users	
Province	Air-dry kg /year	Oven-dry kg /year	kg of charcoal /year	wood equivalent (kg od/year)	Air-dry kg /year	Oven-dry kg /year	kg of charcoal /year	wood equivalent (kg od/year)
Kigali					338	277	182	828
South	378	309	162	735	348	285	219	996
Other					388	318	105	477

[13] In the absence of solid references on the current carbonization rates in Rwanda, a value of 12% has been considered representative of the current situation (Kammen and Lew, 1995; BEST; Murererehe, personal communication). Equally, the value of 18% has been considered feasible as result of a series of actions aiming at rationalizing and improving the efficiency of charcoal making between now and 2020. The implementation of an adequate number of field measurements is an urgent necessity, and it is strongly recommended, in order to produce reliable evidence for the revision of these preliminary values.

Figure 6: Population distribution maps. Top left map detail: Population values associated to "10 HH points " in rural areas and to urban polygons in urban areas. Bottom Map and map detail: population distribution "smoothed" by averaging pixel values within a 1.5 km circle.



2.1.1.1 LPG and biogas penetration trends

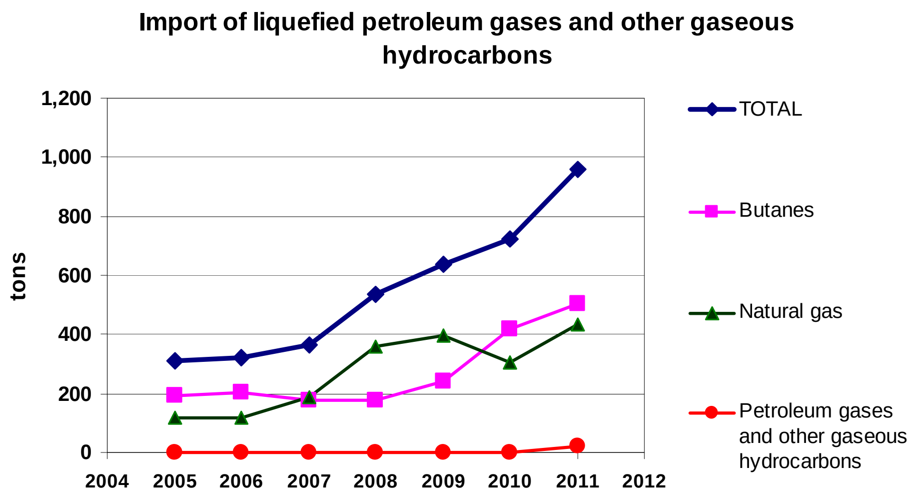
LPG penetration in urban households

Penetration of LPG in Rwanda is still relatively limited, but the situation is evolving rapidly, as may be deducted from the sharp increase of imports in the last few years, as shown in Figure 7.

The monthly sale of LPG by Societé Petroliere (SP) increased from 25 tons in 2010 to 45-48 tons in only 18 months, thanks to an intense promotion campaign, and predicts a steady annual increase of 10-15% per year under current conditions, but could be much higher if some form of subsidy is put in place. The monthly sale by Kobil increased from 10 tons in 2007 to the current 50 tons.

Consumption surveys of urban households do not adequately reflect the increasing penetration of LPG in the energy mix of Kigali households because this evolution is very recent and LPG is often used in combination with charcoal, which remains often the principal cooking fuel. The penetration of LPG in the urban energy mix will significantly influence the role of charcoal in urban households.

Figure 7: Import of LPG 2005 – 2011.



Source: Office of Customs, Rwanda Revenue Authority, 2012

The urban consumption survey indicates that in the city of Kigali LPG is a common cooking fuel for 7.3 % of the households, either alone or mixed with charcoal and others. This value is representative of the true urbanized area and may not be applied to the "urban" area defined by NISR, which includes sub-urban and even rural zones around Kigali. Given the import trend and the economic growth of the country it may be envisaged that the share of Kigali households preferring LPG will increase to 10-15% by 2020. A more accelerated increase to 25-30% is also considered possible, if the price of LPG will be subsidized in order to make it competitive to charcoal. These two levels are used as reference for the BAU and AME scenario, respectively.

Biogas penetration in rural households

The use of biogas as substitute for fuelwood and charcoal in the residential and public sector is evolving fast and will contribute to reduce the consumption of woody biomass for energy between now and 2020. The national biogas program is targeting to reach 9, 500 rural households (approximately 0.4 % of rural households) between 2009 and 2017 and 2,300 biogas systems have already been installed[14]. This transition is part of the 1-2% shift from woodfuels to other fuels in rural households expected between 2009 and 2020 in the BAU and AME scenarios.

2.1.1.2 Fuelwood and charcoal saturation in urban and rural households

Queries about the fuel used for cooking in rural and urban households has been included in most recent surveys, including EICV1, 2 and 3; the RBESS 2009 Survey (MININFRA 2009b). Most surveys report only the principal fuel and thus the role of some "gregarious" fuels, such as farm residues and cow dung, is probably under-represented.

[14] T. Kayumba, Coordinator of National Biogas Program, EWSA, personal communication, October 2012.

The estimated saturation values by province in rural and urban areas resulting from the "blending" of the various references and the urban household survey conducted in the framework of this project are summarized in Table 16.

The difference between 2020 BAU and AME scenarios concerns the higher fraction of LPG within "Other fuels" and a limited shift from fuelwood to charcoal in urban areas. No saturation changes were considered between BAU and AME in rural areas. Additional District-level details on households' consumption parameters are shown in Annex 2.

Table 16: Saturation values of the use of cooking fuels in rural and urban areas used in the analysis. Values based on the elaboration of the results of EICV 1,2 and 3, RBSS 2009 and own collected data.

		Saturation in rural areas (%)			Saturation in urban area (%)			
Province		**Fuelwood**	**Charcoal**	**Other fuels**	**Fuelwood**	**Charcoal**	**Other fuels**	**Notes/assumptions**
Kigali	2009	63.0	36.5	0.5	16.1	76.3	7.6	Other fuels include LPG, electricity, kerosene (urban) and farm residues (rural). Changes between 2009 and 2020BAU are considered physiologic given current trends. AME 2020 scenario implies subsidized LPG (in the Other fuel mix) with shift from Charcoal to Other fuels and from Fuelwood to Charcoal in urban areas only.
	2020 BAU	53.0	45.0	2.0	10	75	15	
	2020 AME	53.0	45.0	2.0	5	65	30	
Southern	2009	95.0	1.5	3.5	69.5	27.5	3.0	
	2020 BAU	92.3	2.2	5.5	66	30	4	
	2020 AME	92.3	2.2	5.5	60	30	10	
Western	2009	94.0	5.6	0.4	68.5	28.7	2.8	
	2020 BAU	90.3	8.7	1.0	66	30	4	
	2020 AME	90.3	8.7	1.0	60	30	10	
Northern	2009	94.0	1.7	4.3	68.5	28.7	2.8	
	2020 BAU	90.3	2.6	7.1	66	30	4	
	2020 AME	90.3	2.6	7.1	60	30	10	
Eastern	2009	94.0	1.7	4.3	68.5	28.7	2.8	
	2020 BAU	90.3	3.6	6.1	66	30	4	
	2020 AME	90.3	3.6	6.1	60	30	10	

Note: It is not possible to assign a statistical confidence interval to the saturation values since the references used did not provide statistical parameters for the breakdown needed (rural/urban and provincial). However, the sample size and confidence interval of the main reference surveys may be indicative: EICV3 (14,300 observations) indicates confidence intervals at 95% probability for charcoal saturation at province level of ± 10% for Kigali, increasing to ± 30-70% for the other provinces, where charcoal saturation values are much smaller. Concerning fuelwood saturation, the indicated confidence intervals for Kigali province are ± 21%, lowering to ± 2-3 % for the other provinces.

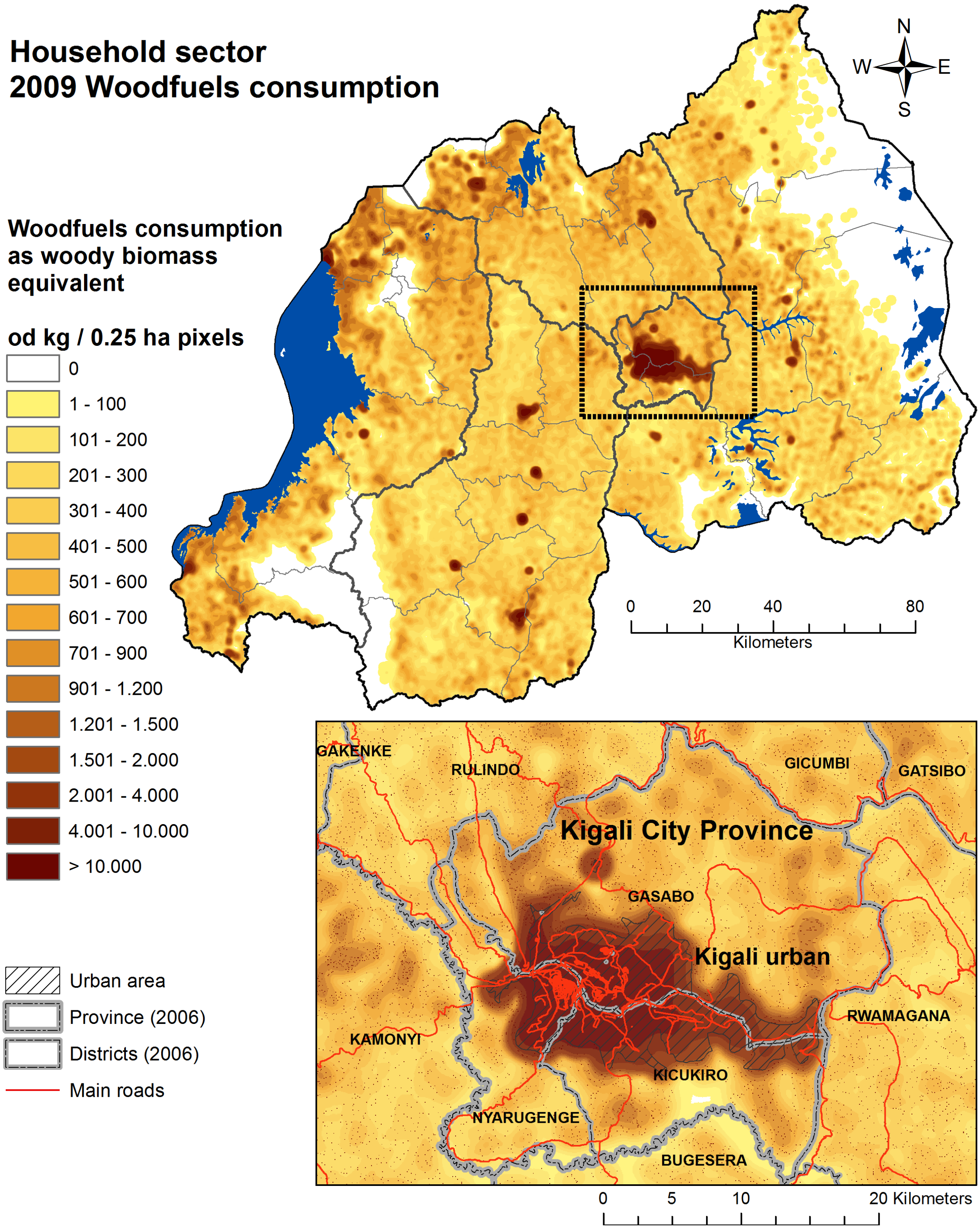
2.1.1.3 Total Household consumption

Figure 8 shows a detail of the map of the 2009 residential consumption of wood and wood-for-charcoal as well as the whole country consumption. The total residential consumption of woodfuels (fuelwood and wood-for-charcoal) in 2009 is estimated at 4.4 million tons (oven dry matter).

The total residential consumption in 2020, according to the business-as-usual (BAU) scenario is estimated at 6.2 million tons (oven dry matter). With ameliorated conversion and charcoal production efficiencies (AME scenario) the residential consumption in 2020 may be constrained to 4.8 million tons.

Detailed District-wise values are given in Table 13 further below.

Figure 8: Residential woodfuels consumption map 2009.



Note: The enlarged map detail shows in the background the point data defining households' concentrations in rural areas, urban areas and main roads.

2.1.2 Other sectors' consumption

2.1.2.1 Commercial sector consumption

An important component of the Demand Module is the consumption of the Commercial Sector. As in previous WISDOM analysis, due to lack of data on the consumption by restaurants, bakeries, hotels, etc. the estimation was done based on generic references. Preliminarily and tentatively, the commercial consumption was estimated as 10 % of urban HH consumption (ref. Drigo 2008 [WISDOM Mozambique]; ref Ministry of Infrastructure, 2009a [BEST]). The 2009 commercial sector consumption is estimated at 125 thousand tons (oven dry matter) and, missing more direct evidence, its geographic distribution is assumed to be directly related to urban populations. Tentatively, 2020 BAU and AME scenarios for the commercial sector are assumed to follow directly those of the residential sector in urban areas (from which the values are derived).

The total commercial sector consumption in 2020, according to the BAU scenario, is estimated at 195 thousand tons (oven dry matter). Assuming improved conversion efficiencies similar to that of the residential sector (AME scenario), the commercial sector consumption in 2020 is estimated to decrease to 115 thousand tons. Detailed District-wise values are given in Annex 2, Table A2.5.

Charcoal consumption by residential and commercial sectors

Charcoal has a special role in the wood energy context and deserves a special attention. Charcoal is the preferred fuel in urban areas and, unlike fuelwood, it is a commercial commodity with a conspicuous and well defined market. Figure 9 shows the concentration of charcoal consumption in 2009, where the role of Kigali predominates, followed by the other urban areas of the country.

Table 17 provides Province-wise summary of charcoal consumption in rural and urban areas in 2009 and 2020 according to BAU and AME scenarios. Distric-wise values are shown in Annex 2, Table A2.7. Rural consumption is limited to the household sector, while the urban consumption includes the tentatively estimated share of the commercial sector.

The urban area of NYARUGENGE, GASABO and KICUKIRO Districts, which may be simply defined as "Kigali", dominates with a consumption of 136 thousand tons in 2009. This represents 80% of the total urban consumption and 60% of the whole national charcoal consumption.

By 2020, the Kigali demand for charcoal may rise to 200 thousand tons, according to the BAU scenario, or to "only" 163 thousand tons, if the strong penetration of LPG assumed in the AME scenario materializes. In any case Kigali will remain the main and major charcoal market of the country, but the demand in other urban areas is likely to increase significantly (from 20% of the total urban demand in 2009 to 26-27% in 2020, depending on the scenario chosen).

Figure 9: Charcoal consumption by residential and commercial sector in 2009.

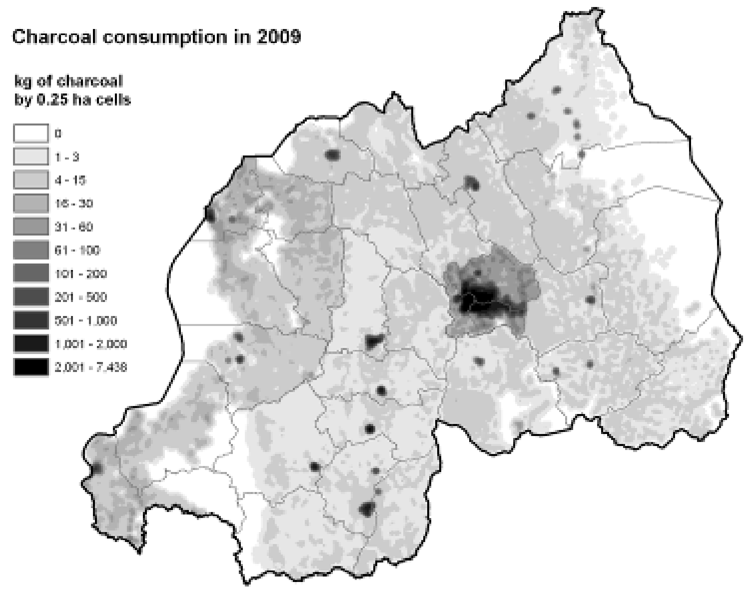


Table 17: Province-level summary of charcoal consumption in 2009 and projected consumption in 2020 according to BAU and AME scenarios. Summary of household and commercial consumption. ('000 tons of charcoal)

	Charcoal consumption 2009 (kt)			Charcoal consumption 2020 - BAU scenario (kt)			Charcoal consumption 2020 - AME scenario (kt)		
Province	**Rural**	**Urban**	**Total**	**Rural**	**Urban**	**Total**	**Rural**	**Urban**	**Total**
KIGALI CITY	11.8	136.2	148.0	14.2	199.6	213.8	13.1	162.6	175.8
SOUTHERN	5.8	19.9	25.7	10.1	43.6	53.7	9.3	37.9	47.2
WESTERN	23.0	6.7	29.7	45.9	10.3	56.1	42.3	8.9	51.2
NORTHERN	5.4	4.9	10.3	10.4	8.6	19.0	9.6	7.5	17.1
EASTERN	9.3	3.2	12.5	22.6	6.2	28.8	20.8	5.4	26.2
Total RWANDA	**55.2**	**171.0**	**226.2**	**103.3**	**268.3**	**371.5**	**95.2**	**222.4**	**317.6**

3.1.2.2 Industrial sector consumption

Concerning the industrial demand of woodfuels, important actors are: Tea factories and brick making.

Concerning **tea factories**, main elements for the estimation and mapping of fuelwood consumption are the map showing their location and data on fuelwood consumption in 2007 and 2008 provided by OCIR-Tea. Consumption is assumed at being quasi-constant and the average annual consumption values were used. Consumption of fuelwood in the main tea factories is symbolized in Figure 11. Total consumption by tea factories is estimated at 28 thousand tons (oven dry matter). Detailed District-wise values are given in Annex 2, Table A2.5.

More problematic appears the estimation and mapping related to **brick making,** due to the lack of information on the quantity and distribution of brick factories and on the quantity of bricks produced and fuels consumed. In principle, raw wood should not be used for making bricks because it's forbidden by law, while the use of saw dust and wood residues is allowed[15]. In reality, raw wood is still used, in combination with sawmill residues and exhausted oils in various proportions. The sawmill residues annually produced (77,000 od t, increasing [LTS, 2010]) would cover in good part the estimated need for fuelwood for brick making (approx. 83,000 od t) but their location and competitive uses reduce the amount actually available for brick making. Moreover, brick makers say that fuelwood produces better quality bricks than saw dust and hence fuelwood is still widely used. The current policy is to use **peat** instead of wood but wood continues to be preferred (illegally). Discouraging measures include fines of up to 50,000 RWF to wood users and or seizure of the whole kiln production for public use.

It is recommended that this sector of consumption be investigated in detail to fill the information gap.

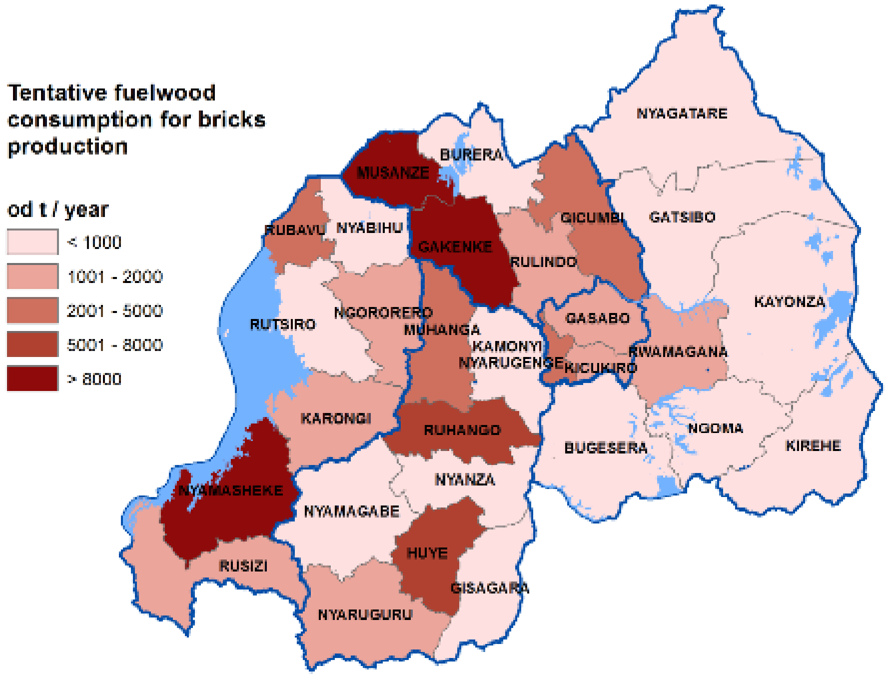
A tentative estimation of wood consumption for bricks production (raw wood and wood residues) was based on sector data collected by PPPMER Programme in 2008, which estimated the presence of over 2,500 brick makers throughout the country, and an annual production of some 267 million bricks. Applying an average per-brick consumption of 0.38 kg of wood (0.31 kg oven dry) [FAO1987 and field interviews], the total consumption for brick production may be tentatively estimated at 82.9 thousand tons (oven dry matter), composed of sawmill residues and "illegal" fuelwood in probably equal proportions. In the near future it should be possible to obtain brick production statistics maintained by the Districts for taxation purposes.

No changes are assumed for the wood consumed for tea curing and brick making between BAU and AME scenarios.

[15] According to LTS Baseline Studies (2010), sawmill residues are estimated at 110,000 m^3 in 2010 , gradually increasing to 179,178 m^3 in 2020, corresponding to 77,000 od t and 125,425 od t, respectively.

The spatial distribution of brick-making's woodfuel demand was estimated, tentatively, based on the statistics provided by District authorities on the distribution of major modern kilns. These statistical records do not include the myriad of small traditional kilns but are indicative of the main production areas. Therefore the overall estimated consumption was distributed among the Districts proportionally to the recorded production capacities, as shown in Figure 10. Estimated District-wise values are given in Annex 2, Table A2.5

Figure 10: Tentative District-wise distribution of fuelwood consumption for bricks production (including sawmill residues and fuelwood).



2.1.2.3 Public sector consumption

A significant amount of fuelwood is used in the public sector, basically by secondary schools and prisons[16].

A new map of the location of **secondary schools** was provided by RNRA Lands Department. The number of students of each school for 2009 and for 2020 was estimated in relation to:

- Data on secondary school students in 2002 (ref NISR Census), which are available at old provinces level,
- EICV 2 and EICV 3 statistics of secondary school attendance (NISR, 2012), and
- National population projections 2007-2022 by NISR (NISR 2009)

In absence of comprehensive countrywide data on fuelwood consumption in secondary schools[17], the consumption per student was preliminarily estimated as ½ of the "standard" per capita consumption using improved stoves, over 9 months.

Mapping of the consumption by the **prisons** is much more reliable since actual consumption of fuelwood by each detention centre was kindly provided by the Director of Prisons and is available for the period 2006-2008.

The consumption of fuelwood in secondary schools and prisons is symbolized in Figure 11. Total consumption by secondary schools and prisons in 2009 is estimated at 35 thousand tons (oven dry matter) and 32 thousand tons, respectively. The consumption by secondary schools and prisons will change between 2009 and 2020 according to the increase of the students' population. According to the BAU scenario, whereby the per capita consumption remains constant while the students' population more than doubles, the consumption of secondary schools in 2020 is estimated at 74 thousand tons.

Assuming a (hopeful) decrease of prisons' inmates of at least 25% by 2020 as effect of the progressively reducing proportion of genocide-related inmates (through mass releases or serving ends) and of the relatively low crime rate of the country, the estimated BAU consumption is tentatively estimated at 24 thousand tons.

Fuel-efficient stoves are widely used in schools and prisons and therefore their use is already assumed in the BAU scenario. The ameliorated (AME) 2020 scenario in this case implies the partial substitution of fuelwood by alternative renewable and non-renewable fuels and by the reduction of boarding in favor of daily attendance (MINEDUC, 2003). Very tentatively, the fuel substitution and the attendance trend are estimated to reduce the per-student consumption by 50% in 2020, with a consequent consumption by secondary schools of 37 thousand tons[18].

If fuel substitution in prisons will be as much as 50% by 2020 (AME scenario) the consumption would lower to 12.1 thousand tons[19].

Detailed District-wise values of woodfuels consumption in the public sector are given in Annex 2, Table A2.5.

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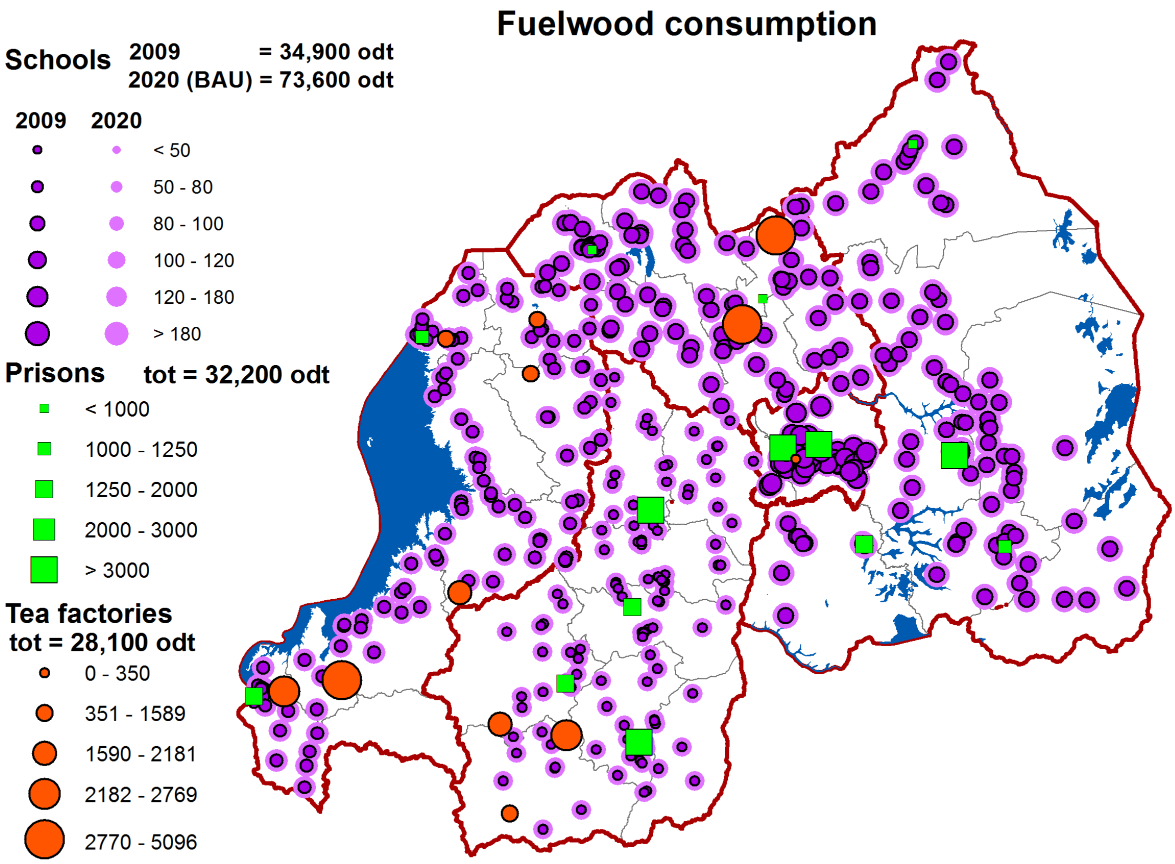
[16] According to ministerial sources, hospitals are no longer using fuelwood and army barracks use only small quantities.

[17] The 2011 MININFRA study on public secondary boarding schools covered 120,000 students out of a students population estimated at 318,000 in 2009.

[18] Information that became available after the analysis of the Demand Module indicates that the saving of fuelwood in the public sector due to biogas program may be much more significant, in relative terms: The country is targeting to reach virtually all public institutions by 2017 and now 68 digesters are operational in 45 schools (approximately 10% of all schools), 1 hospital, 11 prisons (68 % of all prisons) and 11 other institutions (A. Mukashyaka, Institutional Biogas Program, EWSA, personal communication). This means that, if the program is fully successful, the reduction of fuelwood consumption in secondary schools and prisons will be higher than estimated in the AME scenario (50%). Considering this, the total demand in 2020 for the AME scenario should be reduced by 38 thousand tons, or 0.9 %, indicatively.

[19] See previous footnote.

Figure 11: Fuelwood consumption by Secondary Schools, Prisons and Tea factories.



2.1.2.4 Consumption of construction material

The consumption of poles for construction of houses, huts, stables, fences, etc., (*bois de service*) represents alternative uses (to energy) that need to be estimated and mapped in order to be deducted from the total sustainable productivity and to estimate the resources finally available for energy uses.

As no information was available concerning the quantity and location of the construction material annually consumed, reference was again made to other studies (Drigo et al. 2008 [WISDOM Mozambique]) and resulting values were discussed with qualified informants.

The value we arrived at is 86.4 air dry Kg per household per year, or 18 air dry kg per capita (corresponding to 14.7 oven-dry kg).

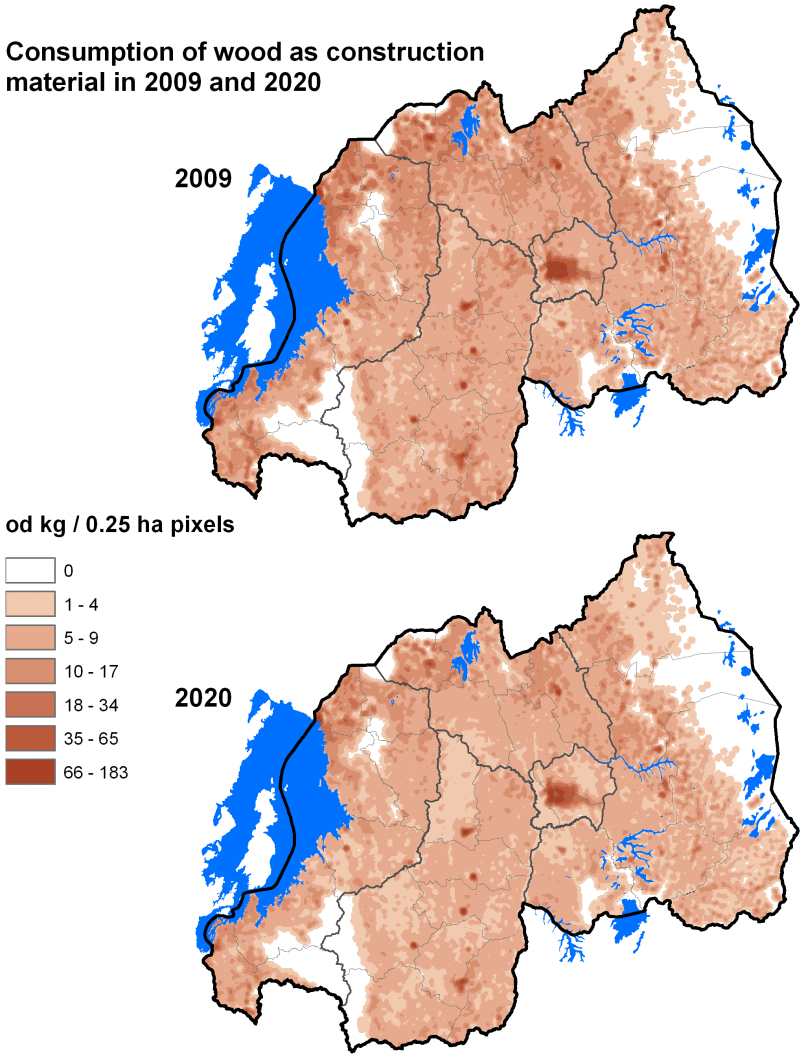
The value mentioned above was then applied to the rural and urban population with reference to EICV2 and EICV3 data (NISR 2012) on house building materials and their change over time. Particularly, the parameters considered correspond to the fraction of houses using tree trunks with mud and/or cement in wall construction in the two survey periods 2005 and 2010 in rural and urban areas. EICV data show a clear decrease in the fraction of "wood" houses between 2005 and 2010 in all provinces, with an overall annual compound rate of -7.3% in urban areas and -5.1% in rural areas. The fractions of wood houses in 2009 and 2020 were estimated through interpolation/extrapolation.

The resulting map of construction material annually consumed in 2009 and 2020 is shown in Figure 12.

In the long term, at the end of its "service" life, a significant part of the old construction wood is also used as fuel. However, in spite of this postponed energy role, it is essential to exclude "fresh" construction wood from the productivity potentially available for energy. Such exclusion allows the identification of the construction material as a specific non-energy forest management product. In addition, the construction wood recovered and used as fuel should be considered as a non-conventional fuel and should not be accounted against conventional fuelwood production potential.

The total consumption of construction material is estimated at some 67 thousand tons (oven dry matter) in 2009 and 52 thousand tons in 2020. No changes are here assumed between BAU and AME scenarios. Detailed District-wise values are given in Annex 2, Table A2.4.

Figure 12 : Consumption of woody biomass as construction material in 2009 and 2020. Although not an energy use, this is a non-industrial consumption component to be deducted from the supply potential.



2.1.3 Total consumption

The maps of the total consumption of woody biomass in all sectors in 2009 and in 2020 according to the BAU and AME scenarios are shown in Figure 13. The total consumption of woody biomass (as fuelwood and wood for charcoal or as construction material) according to BAU scenario is estimated at 4.8 million tons (oven dry matter) in 2009, rising to 6.6 million tons in 2020 according to BAU scenario. With ameliorated efficiencies and increasing penetration of alternative fuels (AME scenario) the total consumption in 2020 could be limited to 5.2 million tons.

The Province-level summary of woody biomass consumption by sector in 2009 and 2020 consumption scenarios is presented in Table 18. See Annex 2 for detailed District-level consumption parameters and sector-wise consumption.

Figure 13: Spatial distribution of woody biomass consumption in 2009. Values report the estimated consumption of oven-dry woody biomass (as fuelwood and wood for charcoal or as construction material) in Kg per 0.25 ha pixel.

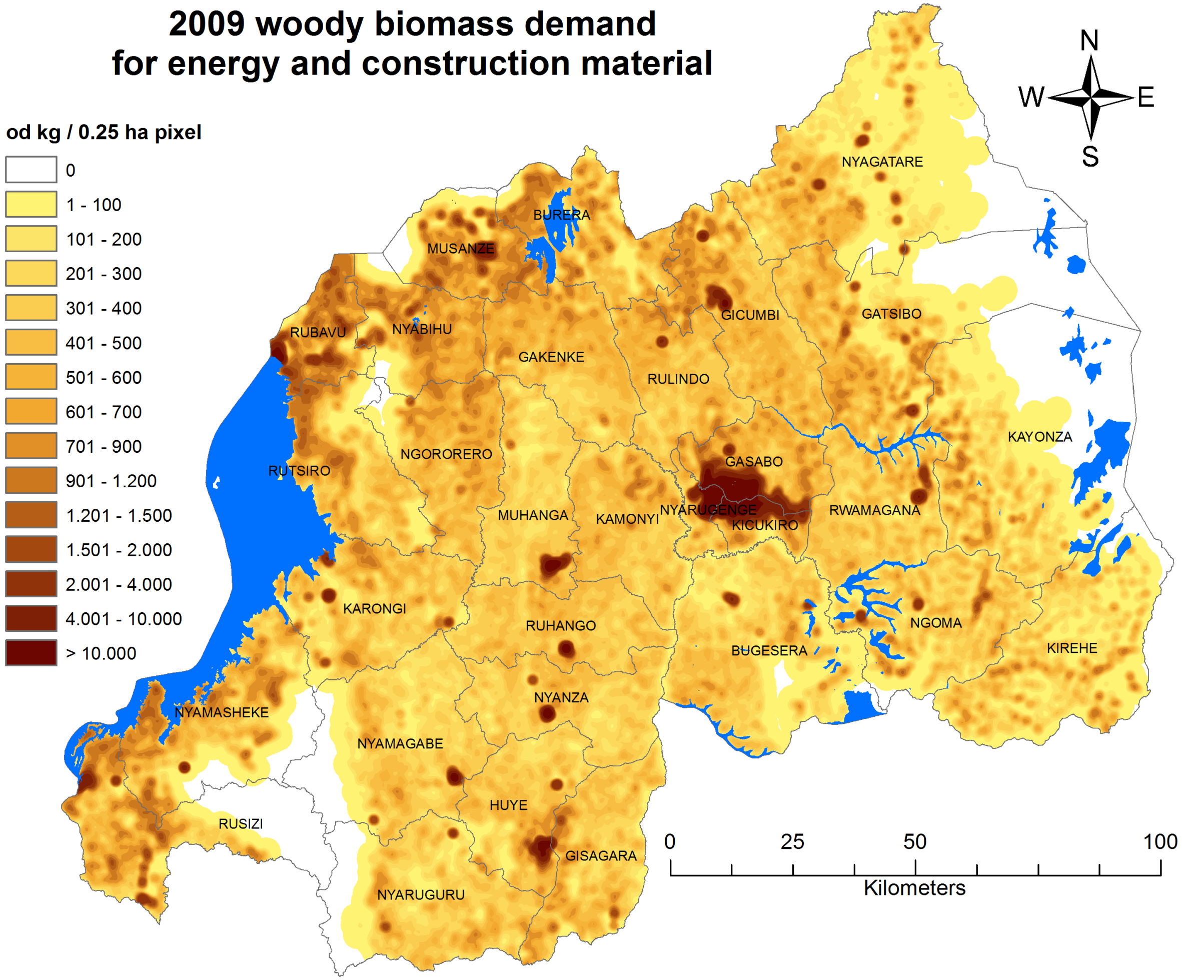


Table 18: Provincial summary of woody biomass consumption in 2009 and 2020 consumption scenarios. Values are thousand tons oven-dry of woody biomass or wood-equivalent in case of charcoal.

	Kigali City	Southern	Western	Northern	Eastern	Total Rwanda
2009 Consumption						
Households' fuelwood consumption [b]	79	758	778	597	778	2,990
Households' charcoal consumption [a]	925	163	200	67	84	1,439
Households' total woodfuels consumption [a]	**1,004**	**921**	**978**	**664**	**862**	**4,429**
Households' construction wood consumption	5	17	178	134	17	69
Total household consumption [a]	**1,009**	**938**	**9958**	**677**	**879**	**4,497**
Commercial woodfuels [a]	89	18	88	6	4	125
Secondary schools	7	7	78	6	7	35
Prisons	9	11	3	2	8	32
Tea factories	0	6	14	9	0	29
Brick making	5	18	21	33	6	83
Total 2009 woodfuels and construction wood [a]	**1,117**	**999**	**1,049**	**733**	**904**	**4,801**
2020 BAU consumption scenario						
Households' fuelwood consumption	69	915	967	742	1,118	3,811
Households' charcoal consumption [a]	1,335	339	376	124	192	2,365
Households' total woodfuels consumption [a]	**1,404**	**1,254**	**1,343**	**865**	**1,310**	**6,176**
Households' construction wood consumption	3	12	13	10	15	52
Total household consumption [a]	**1,407**	**1,265**	**1,356**	**875**	**1,325**	**6,228**
Commercial woodfuels [a]	128	38	12	10	7	195
Secondary schools	12	14	15	15	17	74
Prisons	6	9	2	1	6	24
Tea factories	0	6	14	9	0	29
Brick making	5	18	21	33	6	83
Total woodfuels and construction wood - 2020-BAU [a]	**1,558**	**1,350**	**1,421**	**943**	**1,361**	**6,632**
2020 AME consumption scenario						
Households' fuelwood consumption	47	836	889	681	1,030	3,482
Households' charcoal consumption [a]	732	200	229	74	118	1,353
Households' total woodfuels consumption [a]	779	1,036	1,118	755	1,148	4,836
Households' construction wood consumption	3	12	13	10	15	52
Total household consumption [a]	**782**	**1,048**	**1,130**	**764**	**1,163**	**4,887**
Commercial woodfuels [a]	69	25	9	7	5	115
Secondary schools	6	7	8	7	9	37
Prisons	3	4	1	1	3	12
Tea factories	0	6	14	9	0	29
Brick making	5	18	21	33	6	83
Total woodfuels and construction wood - 2020-AME [a]	**866**	**1,108**	**1,182**	**822**	**1,186**	**5,163**

Note: Totals may not tally due to rounding.

[a] Charcoal consumption is expressed as wood-equivalent assuming 12% charcoal yield for 2009 and 2020 BAU scenario and 18% for the 2020 AME scenario.

[b] Estimated fuelwood consumption here includes conventional fuelwood from tree stems and branches as well as marginal wood products such as twigs, deadwood and pruning of trees and shrubs that are often used by rural households.

2.1.4 Woodfuel consumption in Kigali

In order to quantify the demand exerted by Kigali, Table 19 provides an overview of all parameters that were applied in the estimation of the woodfuels consumption in the Capital city in 2009 and for the development of 2020 BAU and AME scenarios.

Table 19: overview of woodfuel consumption in Kigali in 2009 and in 2020 according to BAU and AME scenarios

	Units [a]	2009	2020 BAU scenario	2020 AME scenario
Estimated Kigali Urban population	Persons	**839,088**	**1,249,983**	**1,249,983**
Household sector (HH)				
HH Saturation: Fuelwood	%	16.1	10	5
HH Saturation: Charcoal	%	76.3	75	65
HH Saturation: Others	%	7.6	15	30
HH Fuelwood consumers	Persons	135,036	124,977	62,488
HH Charcoal consumers	Persons	639,681	937,324	812,347
Per capita annual HH consumption: Fuelwood	kg air dry	366	366	338
Per capita annual HH consumption: Charcoal	kg Ch	194	194	182
Per capita annual HH consumption: Fuelwood	kg oven dry	299	299	277
Per capita annual HH consumption: Charcoal	kg od, wood eq.	1320	1320	828
HH Fuelwood consumption	t od_t	**40,399**	**37,389**	**17,297**
HH Charcoal consumption	t of Ch	123,830	181,448	147,847
HH Charcoal consumption	t od, wood eq.	**844,608**	**1,237,603**	**672,280**
Total HH woodfuels consumption	t od, wood eq.	**885,007**	**1,274,992**	**689,577**
Construction wood	t od	3,356	2,497	2,497
Commercial sector				
Commercial Fuelwood consumption	t od, wood eq.	4,040	3,739	1,730
Commercial Charcoal consumption	t of Ch	12,383	18,145	14,785
Commercial Charcoal cons. (wood equivalent)	t od, wood eq.	84,461	123,760	67,228
Total Commercial cons. (wood equivalent)	t od, wood eq.	**88,501**	**127,499**	**68,958**
Public sector				
Secondary Schools' Fuelwood consumption	t od	6,814	12,071	6,036
Prisons' Fuelwood consumption	t od	8,476	6,357	3,178
Total public sector	t od	**15,289**	**18,428**	**9,214**
Total Fuelwood - all sectors	t od	63,085	62,053	30,738
Total Charcoal - all sectors	t of Ch	136,213	199,593	162,632
Total Charcoal - all sectors (wood equivalent)	t od, wood eq.	929,069	1,361,363	739,508
Total consumption (wood equivalent)	t od, wood eq.	**992,154**	**1,423,416**	**770,246**

Note: "Kigali" is here intended as the urban fraction of Kigali City Province, as defined by NISR; HH = Households.
[a] Air dry weight refers to the weight of purchase at the market. "wood eq." refers to the wood needed to produce the corresponding quantity of charcoal.

2.1.5 Import/export of charcoal

Along the border areas of the Districts of Rusizi and Rubavu, there are some flows of charcoal to Bukavu and Goma (DRC) while along the border areas of the Eastern province such as Nyagatare there is some in-flow of charcoal from Uganda and Tanzania. The flow is entirely informal, without any formal record. The quantity of charcoal exported and imported is estimated to be rather negligible because it is transported on head.

2.1.6 Rural fuelwood users' adaptability

The true role of farm residues in the mix of cooking fuels used by rural households was never thoroughly clarified. Most surveys defined households' principal cooking fuel and farm residues are usually rather marginal in the resulting statistics. In fact, farm residues are rarely the main fuel, but can be an important complement of fuelwood, especially where wood is scarce.

Fuelwood itself can be made of stem wood or branch wood, which are the more "conventional" fuelwood assortments, or made of twigs, smaller branches and shrub wood (Figure 14), which are wood assortments usually excluded from forest inventories and thus not accounted for among the conventional supply sources.

Figure 14: Fuelwood collected by children in rural areas, composed by twigs and small branches.

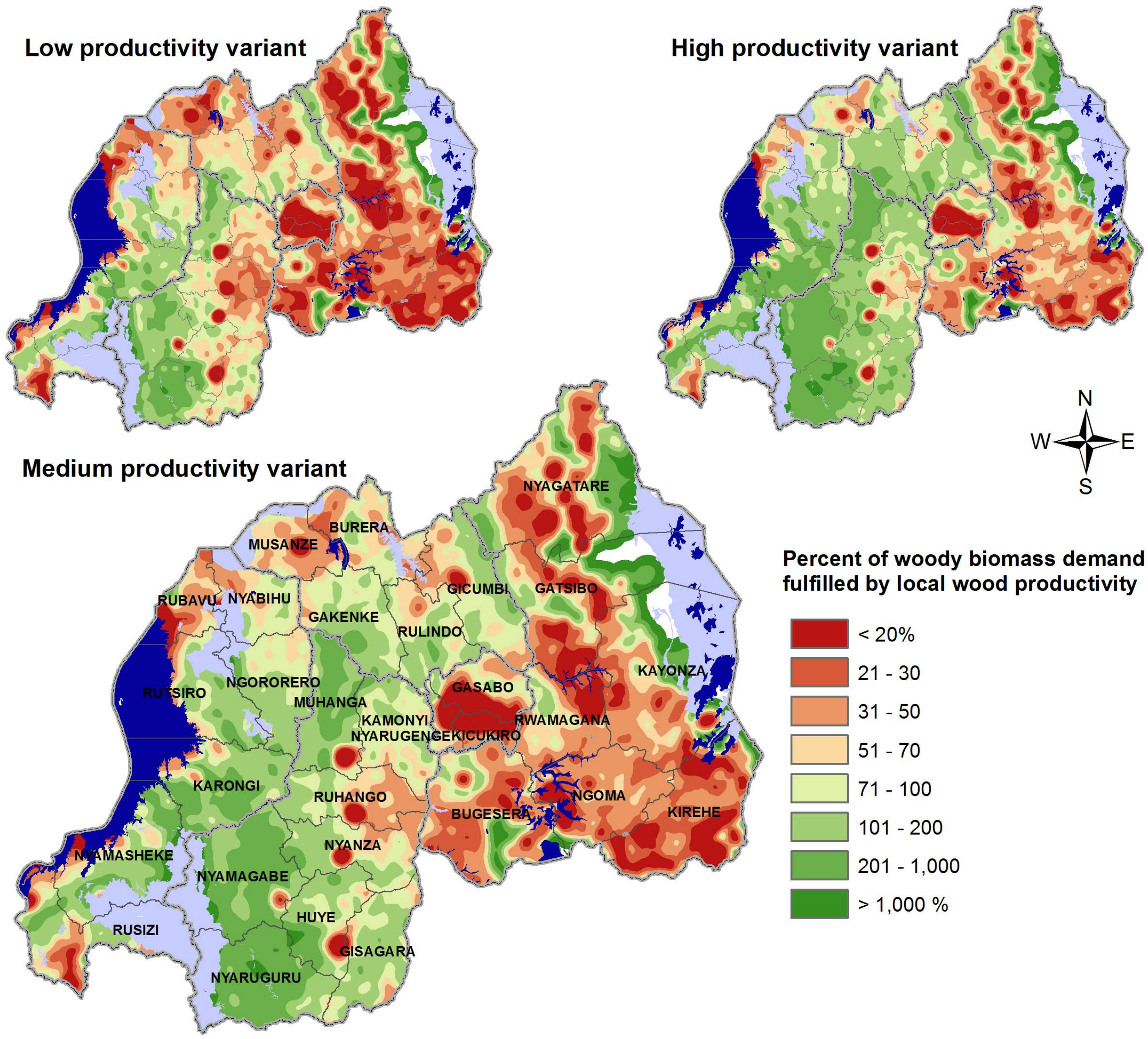
The fuelwood consumption by rural households here reported (see Table 4) is based on available survey data and on the assumption that households demand is made of conventional fuelwood. This may be true for the regions sufficiently rich of forest plantations but it may overestimate the real wood consumption in wood-poor areas, where conventional fuelwood is replaced by twigs, shrub wood, farm residues and dried leaves. This particular component of rural households' consumption should be studied in greater detail as it plays an important role in the overall supply/demand balance as well as in the soil nutrients cycles.

What is the impact of users' adaptability on rural fuelwood consumption?

In rural areas where there is no forest the most likely effect of shortage of "conventional" fuelwood is that rural households use of a higher proportion of twigs and small branches from annual pruning, dry leaves and agricultural residues in the mix of fuels used to satisfy basic households needs. Twigs and small branches that are harvested annually are woody and thus they may be classified as "fuelwood" but they are not accounted for by conventional forest inventories and are <u>not</u> considered in the estimation of the productivity of forest plantations (based on MAI) that includes stem and branch wood available at end rotation (and thinning cycles, if applied). Hence, the consumption of such marginal wood products should not be deducted from the conventional fuelwood productivity. Unfortunately there is no data on the quantity of marginal wood products and farm residues used as fuel in rural households.

In order to quantify, at least tentatively, the impact of wood scarcity on consumption regimes, the rural consumption of "conventional" fuelwood was reviewed in relation to the local supply potential. Figure 15 shows the percent of woody biomass demand fulfilled by local wood productivity according to the Low, Medium and High productivity variants.

Figure 15: Elaboration of supply/demand balance maps showing the percentage of woodfuel consumption potentially fulfilled by local resources, for three variants of standing biomass productivity.



The rural fuelwood consumption in wood-scarce areas was hence reviewed assuming that, depending on the level of scarcity, up to 30% of the fuel demand may be satisfied by "marginal" fuelwood (twigs and small branches from annual pruning of trees and shrubs), dry leaves and agricultural residues, rather than by ordinary fuelwood from the felling of trees and shrubs. To be noted that the 30% limit in the substitution of conventional fuelwood by marginal wood products and farm residues was arbitrarily selected and may be conservative. Other thresholds could be applied but the best approach would be to survey the situation in the field as soon as possible. The reduction of the demand for conventional fuelwood was applied only on rural areas, which depend primarily on local and mostly informal supply. The urban demand for conventional fuelwood was not modified since the supply in this case is formal and market-based.

The results of this revision are shown in Table 20, while the impact of the revised consumption rates on the supply/demand balance of "conventional" wood is shown in Table 26 in the Integration Module Section.

Table 20: District-wise summary of 2009 "conventional" woodfuels consumption vis-à-vis the total woody biomass consumption. The (probable) fraction conventional fuelwood use in rural areas was determined in relation to the local availability of fuelwood sources applying Low, Medium and High productivity variants and a 30% maximum substitution.

District	(a) 2009 total woody biomass consumption	Estimated 2009 consumption of "conventional" woodfuels, excluding marginal wood products					
		Relative to **Low Productivity**		Relative to **Medium Productivity**		Relative to **High Productivity**	
	kt od	kt od	fraction of (a)	kt od	fraction of (a)	kt od	fraction of (a)
NYARUGENGE	317.4	314.2	0.99	**315.1**	0.99	316.0	1.00
GASABO	474.6	457.7	0.96	**461.7**	0.97	465.7	0.98
KICUKIRO	325.1	322.3	0.99	**322.3**	0.99	322.3	0.99
NYANZA	122.4	102.5	0.84	**108.7**	0.89	115.0	0.94
GISAGARA	117.6	95.0	0.81	**104.6**	0.89	114.2	0.97
NYARUGURU	107.4	103.9	0.97	**105.7**	0.98	107.5	1.00
HUYE	146.7	132.7	0.90	**138.7**	0.95	144.6	0.99
NYAMAGABE	129.0	127.4	0.99	**128.3**	0.99	129.2	1.00
RUHANGO	122.7	98.6	0.80	**104.2**	0.85	109.9	0.90
MUHANGA	140.8	135.7	0.96	**138.1**	0.98	140.6	1.00
KAMONYI	111.9	81.5	0.73	**94.4**	0.84	107.3	0.96
KARONGI	144.3	134.3	0.93	**137.6**	0.95	140.9	0.98
RUTSIRO	125.4	101.7	0.81	**108.4**	0.86	115.1	0.92
RUBAVU	178.7	146.3	0.82	**147.8**	0.83	149.3	0.84
NYABIHU	128.2	90.5	0.71	**99.2**	0.77	107.9	0.84
NGORORERO	133.6	105.9	0.79	**117.2**	0.88	128.4	0.96
RUSIZI	170.7	137.3	0.80	**142.0**	0.83	146.6	0.86
NYAMASHEKE	167.5	137.0	0.82	**144.9**	0.87	152.9	0.91
RULINDO	105.4	79.5	0.75	**88.2**	0.84	96.8	0.92
GAKENKE	135.5	102.7	0.76	**116.6**	0.86	130.5	0.96
MUSANZE	160.1	126.1	0.79	**128.6**	0.80	131.0	0.82
BURERA	121.3	85.3	0.70	**90.6**	0.75	95.9	0.79
GICUMBI	210.6	168.5	0.80	**179.5**	0.85	190.6	0.90
RWAMAGANA	116.0	88.5	0.76	**90.6**	0.78	92.7	0.80
NYAGATARE	149.3	117.5	0.79	**118.7**	0.79	119.9	0.80
GATSIBO	163.9	118.7	0.72	**121.5**	0.74	124.3	0.76
KAYONZA	112.2	79.1	0.70	**79.6**	0.71	80.2	0.71
KIREHE	111.5	78.1	0.70	**78.1**	0.70	78.2	0.70
NGOMA	114.4	84.4	0.74	**84.4**	0.74	84.5	0.74
BUGESERA	137.0	100.2	0.73	**101.3**	0.74	102.4	0.75
Total Rwanda	**4,801**	**4,053**	**0.84**	**4,197**	**0.87**	**4,340**	**0.90**

The exclusion of marginal non-commercial wood products and farm residues from the supply/demand balance of conventional woody biomass is probably more realistic than the balance maps based on "standard" demand. But the fraction of these products in the rural fuel consumption is only tentatively estimated and the collection of reliable quantitative field data on the fuel mix used by rural households is strongly recommended.

The impact of the use of these marginal wood products and farm residues is more consistent on the soil fertility than on the forest resources and woody biomass stock as it is normally intended. The impact is on the reduced re-integration of twigs, leaves and residues' nutrients into the soil of forest plantations and agricultural fields. This is likely to produce a progressive loss of soil fertility, with consequent reduction of crop productivity and an increased level of vulnerability and worsened living conditions. The nexus between rural subsistence energy and soil fertility in Rwanda appears deep and far reaching and it certainly deserves a dedicated analysis.

The relation between the use of commercial fuelwood, non-commercial wood products and farm residues for energy is an issue that deserves further analysis based on the present WISDOM dataset and, most important, that requires further investigation and data collection.

2.2 SUPPLY MODULE

2.2.1 Forest Cover Map

The forest cover map produced by CGIS-NUR through interpretation of the 2009 orthophoto coverage provides a thoroughly new perspective on the area under forest plantations and its distribution. As expected, the high resolution of source data (20 cm) allowed an unprecedentedly clear perception of man-made forests, natural forests and shrublands, and facilitated their separation from surrounding land cover types even when presenting low crown cover or small surfaces. The total planted area resulting from the new map, including all plantations greater than 0.25 hectares, is now over 286,000 hectares, which is far greater than the 114,000 hectares estimated by the previous mapping (CGIS-NUR 2007) based on 30 m resolution satellite data[20].

The attributes associated to map polygons were rather heterogeneous, requiring some harmonization and standardization. For the scope of this study, map attributes that are relevant for the estimation of woody biomass stock and sustainable productivity (formations, species composition and density) were standardized.

Table 21 provides the area of plantations species composition and that of natural formations by province. To be noted that in this standardized map legend, in order to keep a manageable number of mixed plantation categories, only the first two species mentioned in the original field "class" were considered.

Eucalyptus species represent 88.7 % of total planted area (which grows to 91 % including mixed formations dominated by eucalyptus) and Pinus species covers 6.6%. All other species are below 1 % of planted area.

Density

The density of plantations and shrub formations was estimated and classified according to crown cover percent of the main canopy. Density categories and numeric codes applied are the following:

0. Undefined
1. Low density - crown cover 10-40%
2. Medium density - crown cover 40-70%
3. High density - crown cover > 70%

Natural forests classes include density in their main definition. Natural forest classes are based on crown cover percent and divided into Closed Natural Forest (CNF), with a crown cover > 50% and Degraded Natural Forest (DNF) with a crown cover < 50%.

[20] The previous map included plantations greater than 0.5 hectares. The different minimum mapping units does not explain the large difference of total plantation area. In fact, according to the new map, the plantations greater than 0.5 hectares cover more than 260,000 hectares.

Table 21: Plantation area by species and natural vegetation formations by province.

Values=area in ha		Province						Protection status		
formation	species	Eastern	Kigali	Northern	Southern	Western	sp. %	Protected	Non-protected	Total
Forest plantation	Acacia kikrii	36					0.01		36	36
	Acacia mearnsii (Black Wattle)	3		0	1	1	0.00		6	6
	Acacia melanoxylon	14	2		921	630	0.55	1,009	557	1,566
	Alnus			3		65	0.02	4	65	68
	Bamboo spp				1	18	0.01	4	16	19
	Callitris	133	8	65	593	154	0.33		952	952
	Mixed: Callitris & Other spp	13			89	4	0.04		105	105
	Cupressus	17	14	20	57	91	0.07	48	152	199
	Mixed: Cupressus & Other spp		1		83		0.03		84	84
	Mixed: Eucalyptus & Acacias	32		47		135	0.07	90	124	214
	Mixed: Eucalyptus & Bamboo			0		96	0.03		96	96
	Mixed: Eucalyptus & Callitris	80	44		91	199	0.14		414	414
	Mixed: Eucalyptus & Cupressus	3	42		14	2	0.02		61	61
	Mixed: Eucalyptus & Grevillea	37	149	19		0	0.07		204	204
	Mixed: Eucalyptus & Other spp	180	35	16	51	10	0.10		293	293
	Mixed: Eucalyptus & Pinus	21	728	18	2,654	985	1.54	6	4,399	4,405
	Mixed: Eucalyptus spp	32,682	9,030	54,059	95,769	62,874	**88.71**	2,527	251,887	254,414
	Grevillea	138	12	13	64	166	0.14		393	394
	Mixed: Grevillea & Other spp	543	27				0.20		570	570
	Jacaranda mimosifolia	215			2		0.08		217	217
	Maesopsis				2	2	0.00		4	4
	Mixed spp (arboretum)				191		0.07		191	191
	Mixed spp (undefined)	303	0	211	810	745	0.72	83	1,985	2,068
	Mixed: Pinus & Eucalyptus		10				0.00		10	10
	Mixed: Pinus & Other spp	11	26		37	31	0.04	3	102	105
	Pinus spp	1,206	98	211	7,874	9,431	**6.56**	3,058	15,762	18,820
	Undefined	274	45	25	684	258	0.45		1,285	1,285
Plantation Total		**35,940**	**10,269**	**54,707**	**109,986**	**75,895**	**100**	**6,830**	**279,967**	**286,797**
Natural Bamboo	Bamboo spp				1,629	4		1,623	10	1,633
Closed Natural Forest	Undefined	72		11,712	31,549	64,769		103,905	4,197	108,102
Degraded Natural Forest	Undefined				9,140	3,416		11,603	953	12,556
Natural shrubs	Undefined	257,844	56	8	571	1,532		59,419	200,592	260,011
Wooded savannah	Undefined	1,773				0		101	1,673	1,773
Total wooded area		**295,629**	**10,325**	**66,426**	**152,875**	**145,616**		**183,479**	**487,392**	**670,871**
Non forest land								74,195	1,619,583	1,693,778
Urban								2	19,101	19,102
Total land area								**257,676**	**2,126,075**	**2,383,751**
Water bodies								0	147,260	147,260
Grand Total								**257,676**	**2,273,335**	**2,531,011**

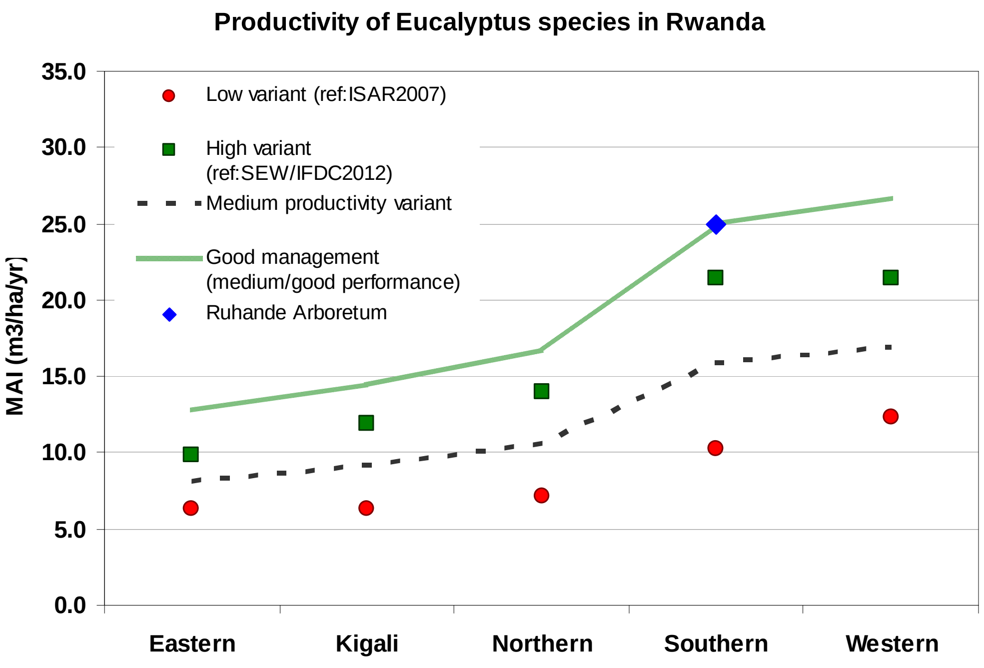
2.2.2 Productivity

Reference data on Mean Annual Increment (MAI) of the various vegetation types of Rwanda is extremely poor and concerned almost exclusively Eucalyptus plantations. Inventory data from ISAR (2007) was limited to the stock of plantation areas, primarily focusing on Eucalyptus. Inventory data on MAI was based on small sample (especially for non-eucalyptus species) and rather difficult to interpret due to the unrecorded influence of coppicing. MAI values for Eucalyptus and for few other species by province, computed for the previous WISDOM analysis are here used as reference for the Low productivity variant, which may well represent public forests of medium to large scale.

More recently, a detailed survey carried out in 18 private Eucalyptus stands by Project SEW/IFDC (Murererehe, 2012) produced stock and growth data that present much higher MAI values than ISAR 2007, which may be representative of the productivity of private stands of small to medium scale. SEW/IFDC results, weighted on stand values, were here used as reference for the High productivity variant.

In order to represent the average productivity of Eucalyptus plantations a Medium productivity variant was defined as intermediate point between Low and High variants. The graph in Figure 16 shows MAI values of Low and High productivity variants as well as the computed Medium productivity variant. In addition, the graph includes an "impression" of what the productivity of Eucalyptus could be if best genetic selection and good management practices are implemented (inferred from research carried out in the Arboretum of Ruhande, Huye, Southern Province, referring to species showing medium/good performance [Burren, 1995]).

Figure 16: The productivity of Eucalyptus plantations in Rwanda .



ISAR data was used to define productivity of Pinus species by province while for several other planted species only tentative national-level values were available. For some other species identified in the forest map there is no reference at all, and the productivity values used are purely indicative. It should be considered, however, that pure and mixed Eucalyptus and Pinus plantations cover 97.3 % of all planted area and that the contribution of other species it is at present rather marginal. Plantation areas by species, density classes and provinces, and selected Mean Annual Increment (MAI) values according to Low and High productivity variants are shown in Annex 3.

Trees outside Forest (TOF)

The TOF survey carried out for the previous WISDOM analysis considered all woody vegetation that was not covered by the CGIS NUR map (2007), which had a minimum polygon size of 0.5 hectares. In order to comply with the new CGIS NUR map that has 0.25 hectares as minimum mapping unit, the vegetation classes of all areas between 0.5 and 0.25 ha were removed from the original TOF survey dataset with the scope of estimating tree and shrub cover only on areas BELOW 0.25 hectares and thus not appearing on the new CGIS NUR map. Table 22 below shows the result of this revision.

In the estimation of the productivity of small woodlots and isolated trees, which are mainly represented by Eucalyptus spp, reference is made to the same two main references used for plantation resources: ISAR 2007 for the Low productivity variant and SEW-IFDC for the High productivity variant. The two references were used to set the reference MAI values at 100% crown cover, which were then applied to the observed crown cover values. Medium productivity variant was then computed as mid-range values.

In the total absence of reference material, the productivity of shrubs and fruit orchards was assumed as 7% of the stock, which may be considered conservative for shrubby biomass formations.

Table 22: Tree Outside Forest survey results (reviewed to represent only wood lots below 0.25 hectares) and preliminary stock and productivity estimates.

Rainfall zone	< 800	800-900	900-1100	1100-1500	>1500	Total
Sample area (ha)	390	1,370	2,000	600	100	4,460
Young trees cover %	0.3	0.5	0.8	1.1	1.3	0.7
Old trees cover %	0.7	0.8	1.7	1.8	2.2	1.4
Total tree cover %	**0.9**	**1.3**	**2.5**	**2.9**	**3.4**	**2.1**
Shrubs cover %	3.0	3.4	2.7	0.4	0.8	2.6
coffee cover %	0.00	0.02	0.71	0.82	0.00	0.44
Tea cover %	0.00	0.00	0.00	0.03	0.61	0.02
Young fruit trees cover %	0.00	0.00	0.00	0.02	0.00	0.004
Old fruit trees cover %	0.00	0.04	0.14	0.23	0.30	0.11
Total Shrubs & fruit trees cover %	**3.0**	**3.5**	**3.5**	**1.5**	**1.7**	**3.2**
Shrubs & fruit trees stock t od ha^{-1} (15 odt ha^{-1} at full density)	0.5	0.5	0.5	0.2	0.3	0.5
Tentative **MAI of TOF - total woody biomass, including twigs and small branches ('000 od t ha^{-1} yr^{-1})**						
Low Tree MAI (ref. ISAR 07 - WISDOM 2009 productivity) (t od ha^{-1} yr^{-1})	0.05	0.09	0.21	0.33	0.48	
High Tree MAI (ref. SEW-IFDC productivity) (t od ha^{-1} yr^{-1})	0.07	0.14	0.35	0.62	0.85	
Shrubs & fruit trees MAI (assuming 7% of stock) (t od ha^{-1} yr^{-1})	0.03	0.04	0.04	0.02	0.02	
Low TOF MAI (t od ha^{-1} yr^{-1})	**0.08**	**0.13**	**0.25**	**0.34**	**0.50**	
High TOF MAI (t od ha^{-1} yr^{-1})	**0.10**	**0.18**	**0.39**	**0.63**	**0.87**	
Accessible Non-forest land area (ha)	**17,782**	**293,768**	**582,408**	**599,521**	**125,952**	**1,619,431**
Low tot TOF MAI kt od yr^{-1}	**1.5**	**37.9**	**145.5**	**206.7**	**63.3**	**455**
Medium variant - tot TOF MAI kt od yr^{-1}	**1.6**	**44.7**	**186.8**	**293.0**	**86.2**	**612**
High tot TOF MAI kt yr^{-1}	**1.7**	**51.4**	**228.1**	**379.4**	**109.1**	**770**

There is a wide consensus on the fact that the contribution of agro-forestry to the supply of woody biomass for household energy consumption is important, but quantitative estimates are extremely scarce. In this estimation we aimed at the production of "conventional" fuelwood, as determined by MAI parameters.

Through the annual collection of twigs and small branches, periodic pruning of trees and shrubs, etc. agro-forestry systems are probably able to produce a much greater amount of household fuels than estimated above[21]. This is a factor of paramount relevance in the understanding of fuelwood supply demand balance in Rwanda, and well-focused quantitative investigations and surveys are therefore strongly recommended.

2.2.3 Accessibility and availability

Accessibility

Physical and legal accessibility of the existing sources of woody biomass was analyzed through integration of the data layers, including (i) cost-distance analysis based on slope, road network, market locations and populated places and (ii) maps of protected areas (IUCN-WCMC, 2009) and of Protected Marshlands (REMA, 2009) that were used to map access limitation to wood resources due to legal reasons.

Physical accessibility

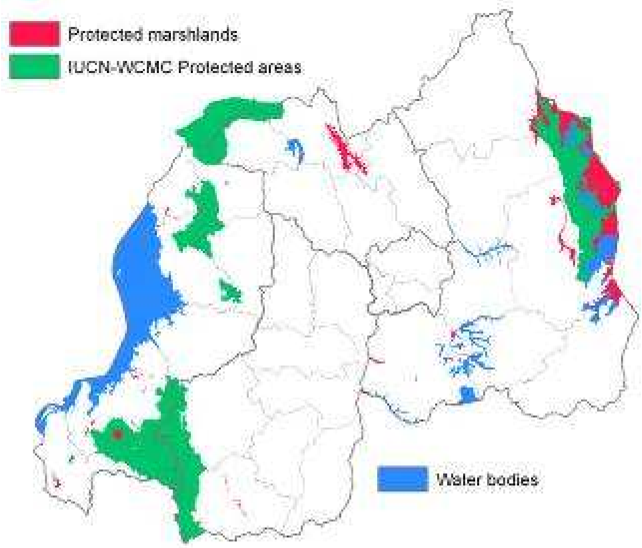
Given the extremely high density of rural population, with over 425 inhabitants per km² in 2010 (increasing to over 550 by 2020), and its diffuse distribution, there are no significant constraints to the physical accessibility of the woody biomass resources in Rwanda. Moreover, discussions with forest managers revealed that even at high slope locations exploitation is allowed if basic soil protection prescriptions are followed, such as selective felling and coppicing rather than clear felling.

Consequently, the cost-distance map was not used for resources accessibility in the supply module. Slope map and cost-distance analysis are very useful anyhow for the analysis and delineation of woodshed, for instance, and for identification of land areas above 55% slope that are suitable for new plantations according to recent land protection prescriptions.

Legal accessibility

Legal accessibility constraints were taken from IUCN-WCMC categories (Figure 17) and their application in the country. Accordingly, no access is allowed to these areas. Another data layer used concerns the protected marshlands. Several protection levels are associated to the map provided. On the basis of such definitions, no access was associated to the areas with "total protection" while for other marsh areas no limitation was given. In any case, grass swamps of the marshlands are no significant producers of woody biomass and therefore are considered as non suitable for wood extraction.

Figure 17: Legal Accessibility: protected areas that determine the legal accessibility of resources (based on IUCN-WCMC,(2009) and REMA (2009))



Availability

The woody biomass resource potentially available for energy applications has been estimated by deducting from the accessible sustainable productivity the other non-energy uses. These include the sawnwood demand, limited to the actual sawn material, since the residues of sawmills are primarily used as woodfuels and thus "available" for energy uses.

[21] In their article, J.D. Ndayambaje and G.M.J.Mohren (2011) cite Samyn (1993), reporting survey data giving average wood production in the farming systems of 1.5 m³ ha⁻¹ year⁻¹, (approximately 1 od t), which is more that twice the productivity here assumed.

Industrial roundwood

LTS baseline studies (LTS, 2010) estimated the national sawnwood demand in 2010 at 90,000 m^3, with an increasing demand reaching 146,600 m^3 by 2020, as shown in Table 23. These values correspond to roundwood values of 200,000 m^3 and 325,780 m^3, respectively.

Table 23: Sawnwood demand and round sawlogs required to meet demand

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Sawnwood demand ('000 m^3)	90	95	99	104	109	115	121	127	133	140	147
Roundwood equivalent at 45% sawing conversion ('000 m^3)	200	210	221	232	243	255	268	281	295	310	326
residues ('000 m^3)	110	116	1216	1276	134	140	147	155	163	171	179
residues (kt od)	77	81	85	89	94	98	103	108	114	119	125

Ref: LTS 2010.

LTS values are much lower than those provided by FAOstat Country Statistics, that indicate 495,000 m^3 of industrial roundwood per year for all recent years. It should be highlighted, however, that this is an estimation offered by FAO in absence of official country data. LTS values were produced as part of a comprehensive in-depth sector review that appears as a more reliable reference than FAOstat for the current analysis. The fraction of woody biomass used as sawnwood (and thus unavailable for energy uses) is now estimated to be as indicated by LTS and thus much lower than assumed in the previous WISDOM analysis, that, in the absence of other available references, used FAOstat values.

Considering that sawmill residues are primarily used as fuel (for brick making, for instance), the quantity of wood to be considered as NON-available for energy uses is limited to the net sawnwood annually produced.

Construction material

Construction material is also an important non-energy wood product. Construction wood is mostly made by poles and un-sawn stem wood, which is not included in the industrial roundwood and sawnwood mentioned above. Given its intimate relation with households, especially in rural areas, it was considered more appropriate to add construction wood to the demand rather than deducting it from the supply potential. The estimation of construction wood consumption is discussed in the Demand Module Chapter (See Figure 12 for spatial distribution and Table 18 for provincial summary).

2.2.4 Total 2009 supply potential

Table 24 provides an overview of the estimated sustainable productivity that may be considered accessible and available for energy uses (i.e. industrial roundwood is here excluded) in 2009 by land cover classes and canopy density. The map of available woody biomass in 2009 is shown in Figure 18.

Table 24 provides also average productivity values and relative reference sources (See Annex 3, Table A3.2 for detailed productivity values applied for plantation species).

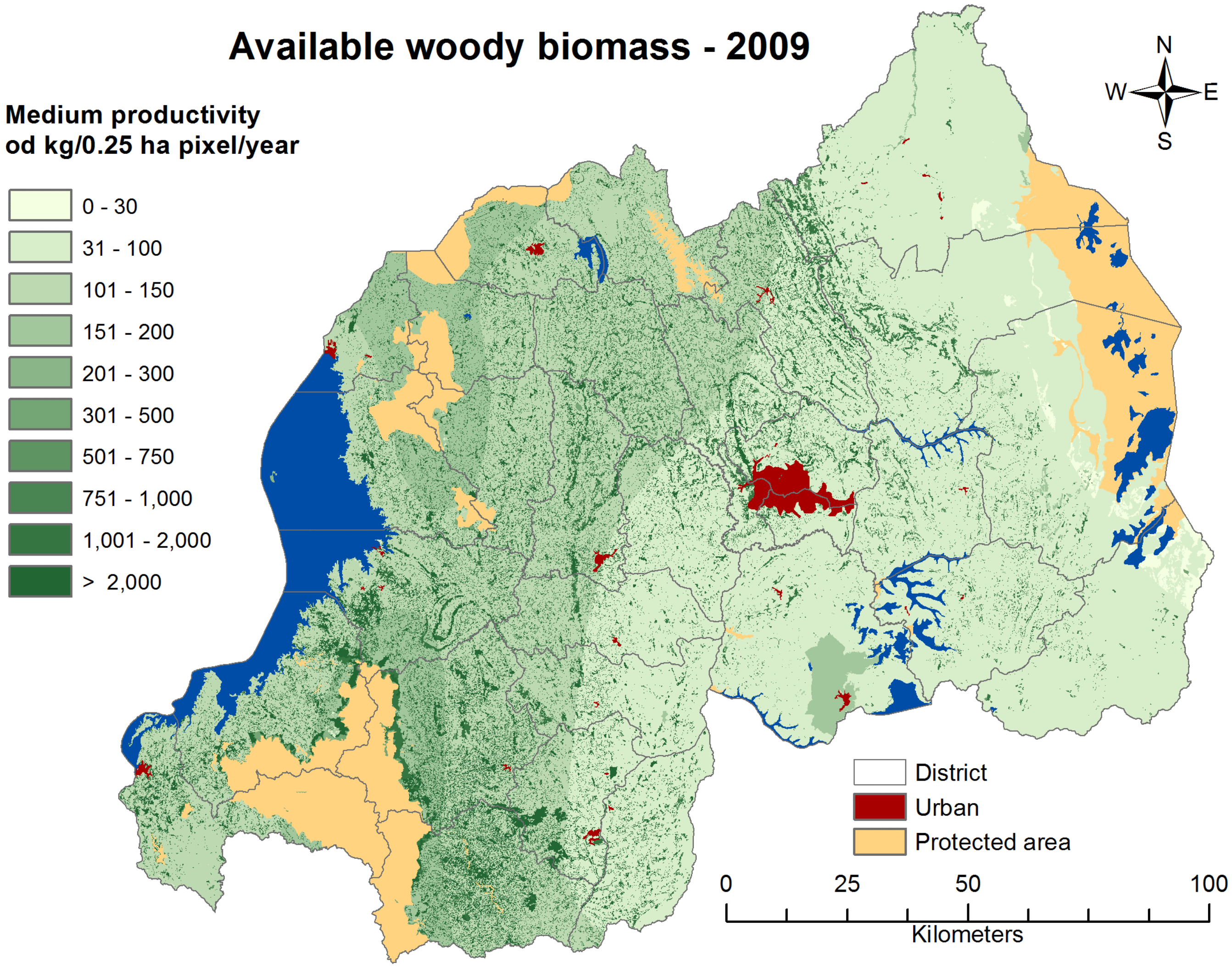
Table 25 shows the total 2009 productivity by Province, including full MAI, accessible MAI and available MAI for each productivity variant. District-wise details are provided in Annex 3 (Table A3.3).

Table 24: Summary of land cover classes by canopy density and their estimated sustainable productivity of woody biomass annually available [a] for energy uses and construction material in 2009.

					Total available productivity [a] (t od / year)			Average available productivity [a] t od/ha/year			References/comments		
Land cover	**density**	**Total area**	**Protected**	**Non Protected**	**Low variant**	**Medium variant**	**High variant**	**Low variant**	**Medium variant**	**High variant**	**Low variant**	**Medium variant**	**High variant**
		ha	ha	ha	t od/yr	t od/yr	t od/yr	t od /ha/yr	t od /ha/yr	t od /ha/yr			
Forest plantation	10-40%	31,256	278	30,978	82,440	120,304	158,249	2.66	3.88	5.11			
	40-70%	137,907	1,721	136,186	806,554	1,169,796	1,533,400	5.92	8.59	11.26	ISAR 2007	Mid-range	SEW-IFDC2011
	>70%	117,634	4,831	112,803	950,017	1,359,346	1,768,927	8.42	12.05	15.68			
Total Forest plantation		**286,797**	**6,830**	**279,967**	**1,839,011**	**2,649,446**	**3,460,577**	**6.57**	**9.46**	**12.36**			
Closed Natural Forest	>=50%	108,102	103,905	4,197	6,984	7,639	8,310	1.66	1.82	1.98			
Degraded Natural Forest	<50%	12,556	11,603	953	1,003	1,121	1,239	1.05	1.18	1.30			
Bamboo	40-70%	1.0	0.0	1.0	0.3	0.4	0.4	0.34	0.39	0.44			
	>70%	1,632	1,623	9	5	6	6	0.52	0.60	0.69	Tentative: WISDOM 09, BAU variant	Mid-range	Tentative: WISDOM 09, MAN variant
Natural shrubs	10-40%	206,032	58,030	148,003	23,088	26,048	29,601	0.16	0.18	0.20			
	40-70%	34,227	1,252	32,976	11,212	12,927	14,641	0.34	0.39	0.44			
	>70%	19,751	138	19,614	10,277	11,847	13,494	0.52	0.60	0.69			
Wooded savannah	10-40%	1	0	1	0	0	0	0.25	0.28	0.32			
	40-70%	911	60	851	473	531	592	0.56	0.62	0.70			
	>70%	861	41	820	705	794	883	0.86	0.97	1.08			
Urban	n.a.	19,102	2	19,101	3,667	4,431	5,195	0.19	0.23	0.27			
Non-forest land (farms and agroforestry)	n.a.	1,693,778	74,195	1,619,583	453,248	611,305	769,938	0.28	0.38	0.48	ISAR 2007, and ToF data	Mid-range	IFDC2011 and ToF data
Water	n.a.	147,260	0	147,260	-	-	-	-	-	-			
Grand Total		**2,531,011**	**257,676**	**2,273,335**	**2,349,674**	**3,326,095**	**4,304,477**	**1.03**	**1.46**	**1.89**			

[a] "Available" includes the mean annual increment that is legally accessible deducted of the annual sawnwood production.

Figure 18: Sustainable productivity of woody biomass available [a] for energy uses and construction material in 2009. Medium productivity variant



[a] "Available" includes the mean annual increment that is legally accessible, deducted of the annual sawnwood production.

Table 25: Supply Module - Province-level summary of woody biomass productivity in 2009 and in 2020 (BAU scenario) according to productivity variants. Values are thousand oven-dry t of woody biomass.

(kt od /yr)	2009- Total Mean Annual Increment (MAI) [a]			Accessible MAI [b] - 2009			Available MAI [c a] - 2009			Available MAI [ca] - 2020		
	Productivity variant			Productivity variant			Productivity variant			Productivity variant		
Province	Low	**Medium**	High	Low	**Medium**	High	Low	**Medium**	High	Low	**Medium**	High
Kigali City	63	**87**	111	63	**87**	111	61	**85**	109	66	**92**	118
Southern	1,003	**1,463**	1,924	929	**1,381**	1,833	903	**1,354**	1,805	980	**1,470**	1,962
Western	900	**1,184**	1,468	738	**998**	1,257	719	**979**	1,239	778	**1,059**	1,340
Northern	390	**559**	729	367	**533**	699	358	**524**	689	385	**564**	744
Eastern	327	**404**	482	313	**390**	466	308	**385**	461	324	**405**	486
Tot Rwanda	**2,683**	**3,698**	**4,714**	**2,411**	**3,388**	**4,365**	**2,350**	**3,327**	**4,304**	**2,533**	**3,590**	**4,650**

[a] Total MAI includes the entire woody biomass growth/re-growth potential, irrespective of location and end use.

[b] The Accessible MAI includes the woody biomass growth/re-growth potential that is legally accessible (protected areas are excluded).

[c] Fraction of the Accessible MAI that is potentially available for energy uses and for construction material, after deduction of the industrial sawnwood.

2.2.5 2020 Supply potential

Some basic considerations are herewith provided:

- There is no evidence of specific land cover dynamics. In fact, they probably exist, but there is no reliable reference data on significant trends on the decrease or increase of forest area. The new forest map is too different from the previous one and therefore no meaningful trend values can be derived (the result would be a 228% increase of plantation area above 0.50 ha between 2007 and 2009!!!).
- As for all mapping exercises, the map reports only visible features. We may therefore assume that the true plantation area is slightly greater than the mapped one, considering that plantation areas harvested or planted at the moment of photo acquisition are probably classified as non-forest. It is difficult to say what such "invisible" fraction could be, but 5 to 10 % of the mapped plantation area may be a reasonable guess.
- On-going forestry and agro-forestry programmes such as PAREF and IFDC are creating new plantation areas (some 10,000 ha of new plantations by PAREF only).

Without considering new particular interventions, it may be assumed that the plantation area in 2020 will be slightly larger than reported in the new forest map (depicting 2009 situation). A 10% increase in plantation area in 2020 as effect of the considerations given above seems to be a reasonable assumption for what may be the BAU supply scenario. Therefore, without special interventions (BAU scenario) the plantation area in 2020 is expected to be 315,500 hectares. Not knowing where the additional plantation area will be located, the effect of this factor has been converted into a 10 % increase of productivity of the mapped plantations.

2.3 INTEGRATION MODULE

The scope of the Integration Module is to combine, by discrete land units (pixels-level and sub-national unit-level), the parameters developed in the demand and supply modules, in order to discriminate areas of potential deficit or surplus according to estimated consumption levels and sustainable production potentials.

The first and most important result of the integration module is the balance between the fraction of the potential sustainable productivity available for energy and total consumption of woody biomass used for energy.

2.3.1 2009 Supply/Demand Balance

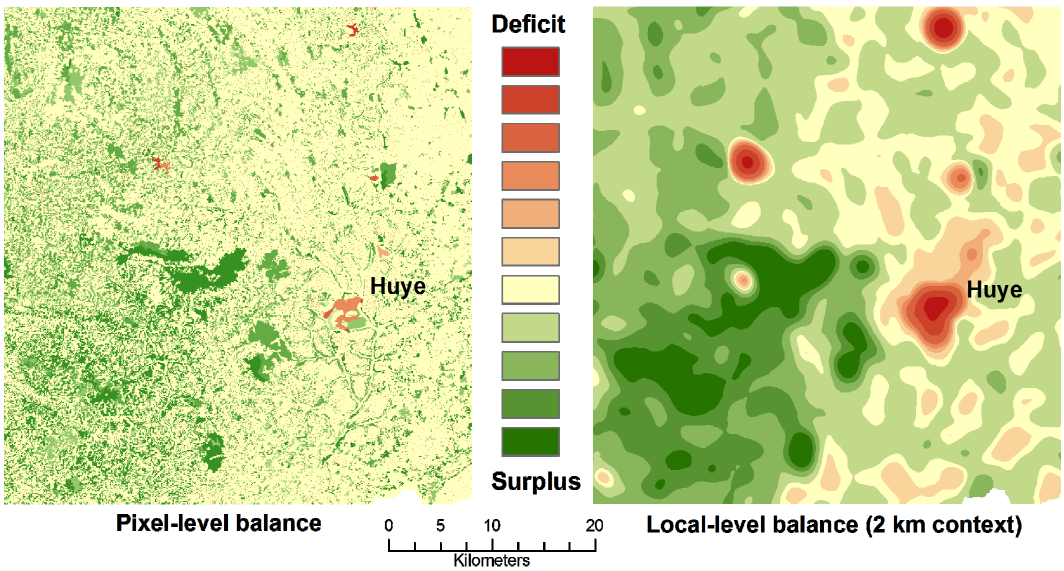
2.3.1.1 2009 Pixel-level balance

The supply/demand balance at the level of individual map pixel (or cell) is calculated by deducting the pixel-level consumption from the pixel-level available productivity. The calculation of the supply/demand balance by individual 0.25-hectare cell is a somewhat virtual balance since individual pixels are usually either a production or a consumption site, but it has a useful accounting function since it allows to calculate and summarize balance values at any chosen level of aggregation. Table 26 shows the District-level summary of woodfuel demand and supply potential according to various productivity variants. Any other reporting unit may be chosen for balance analysis.

3.3.1.2 2009 Local supply/demand balance

In order to achieve a realistic perception of the supply/demand balance it is necessary to combine consumption and supply potential within an area related to the real supply zone. In the case of rural and peri-urban households, the distance that household's members are prepared to go to fetch fuelwood, on foot or by local transport means are good parameters to estimate the actual supply area. In the context of Rwanda, characterized by high population density fairly homogeneously distributed and hilly landscapes, a relatively small household collection horizon of 2 km was applied. Figure 19 shows an example of pixel-level vs. local-level balance.

Figure 19: Example of pixel-level balance (left) and local-level balance



The maps in Figure 20 show the local balance relative to the estimated 2009 woodfuels demand and to the sustainable supply potential according to Low, High and Medium productivity variants.

Table 26: Summary of supply/demand balance in 2009 by Province ('000 tons, oven dry). Values reflect 3 productivity variants.

Values are '000 tons, oven dry matter (kt od)	2009 Available supply potential [a]			2009 Demand [b]			Balance 2009 [d]		
	Woody biomass			Consumption of conventional woody biomass as fuelwood, wood-for-charcoal and construction material			2009 Available supply potential <minus> 2009 Demand		
	Productivity variants			Relative to Productivity level [c]			Productivity variants		
Province	Low	**Medium**	High	Low	**Medium**	High	Low	**Medium**	High
Kigali City	61	**85**	109	1,094	**1,099**	1,104	-1,033	**-1,014**	-995
Southern	903	**1,354**	1,805	877	**923**	968	26	**431**	837
Western	719	**979**	1,239	853	**897**	941	-134	**82**	298
Northern	358	**524**	689	562	**603**	645	-204	**-80**	45
Eastern	308	**385**	461	666	**674**	682	-358	**-290**	-221
Tot Rwanda	2,350	**3,327**	4,304	4,053	**4,197**	4,340	-1,704	**-870**	-36

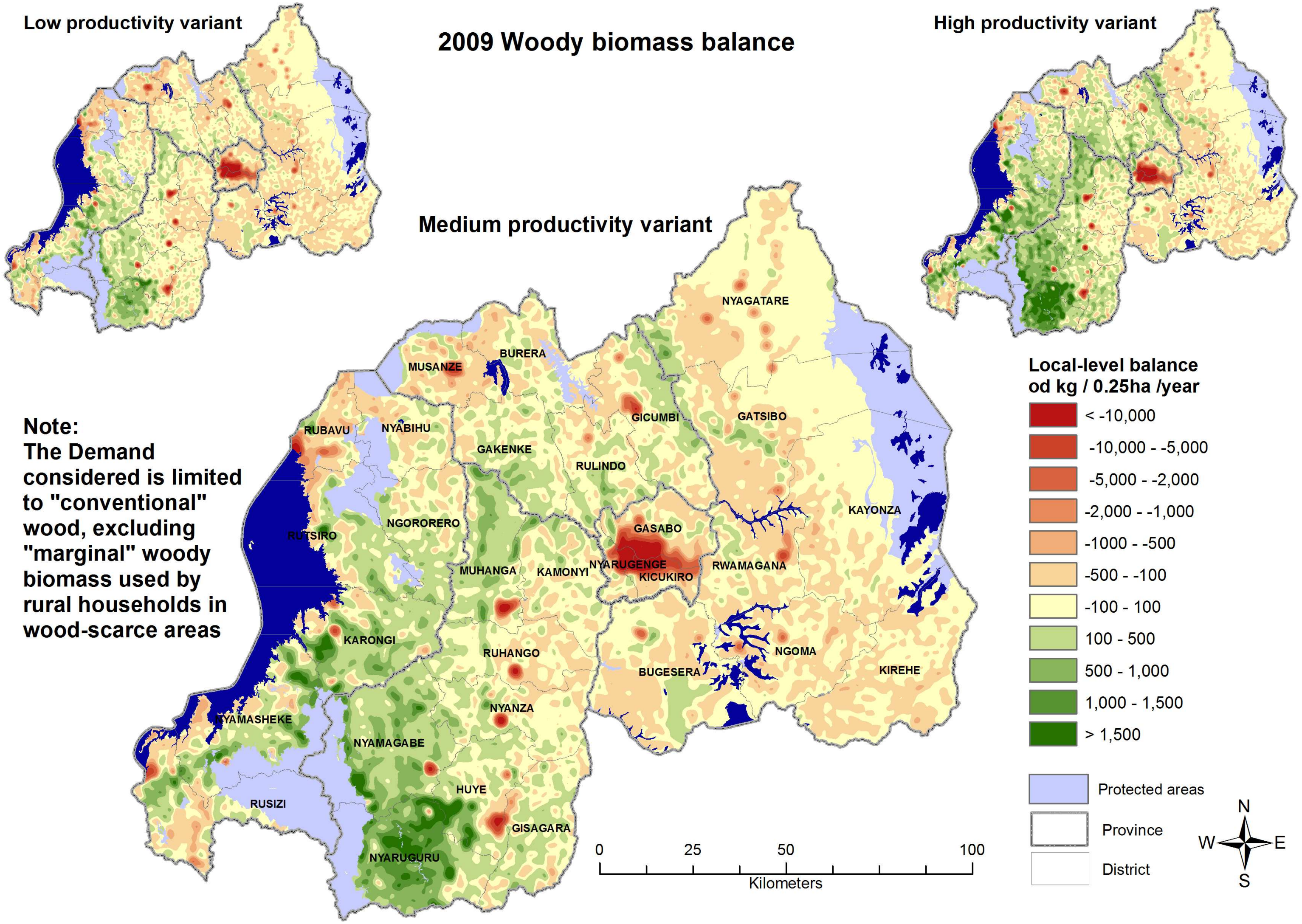
[a] The supply potential here considered includes the fraction of the annual increment of woody biomass (medium productivity variant) that is physically and legally accessible and available for energy and construction material. Sawnwood is excluded but sawmill residues are included. The supply potential is limited to the "conventional" woody biomass (stem and branches from tree harvesting), excluding "marginal" fuelwood sources such as twigs, periodically pruned branches and deadwood, and crop residues.

[b] Demand for woodfuels is limited to "conventional" fuelwood and wood for charcoal and construction material, excluding "marginal" fuelwood sources and crop residues that are often used by rural households.

[c] Different Demand values are estimated for Low, Medium and High productivity variants because the proportion of conventional and marginal wood are expected to change in case of a higher, or lower, availability of conventional fuelwood.

[d] Balance resulting from the available supply potential of conventional wood and the demand for conventional woodfuels and construction material.

Figure 20: Local supply/demand balance map in 2009 based on the demand for conventional wood (excluding marginal woody biomass products used in wood-scarce areas) and Low, Medium and High productivity variants. The analysis is done within a local context (2km).



2.3.1.3 Charcoal supply zones of Kigali

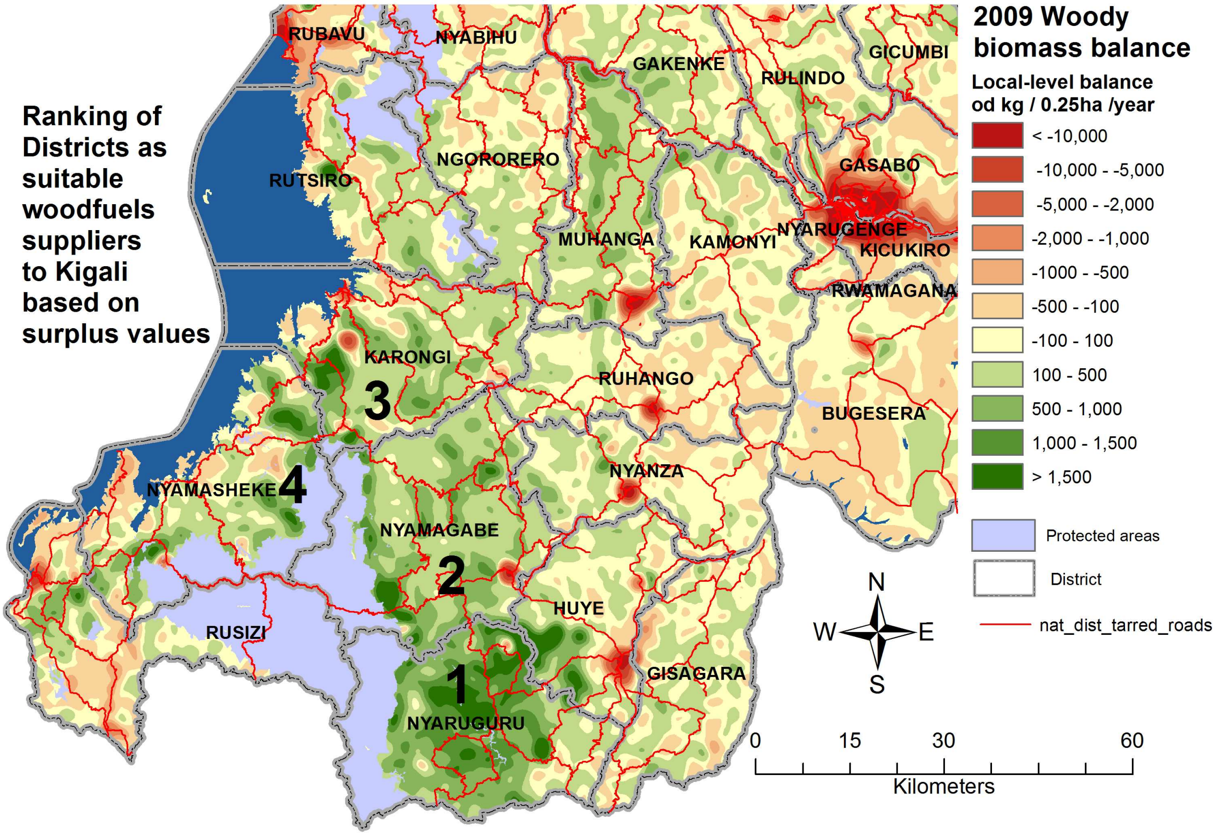
What are the supply sources of charcoal sold in Kigali? We tried to answer this question from two different perspectives: (i) identify current Districts of provenience based on the interview of chain operators (transporters and dealers/retailers) and (ii) identify the Districts that are best suited according to the available woody biomass surplus from WISDOM analysis.

Table 27 summarizes the answers as obtained from 42 transporters and 105 dealers. There is a general agreement that Nyaruguru, Nyamagabe and Karongi are the most important sources of charcoal. Since there are no records on the sources, chain operators express their "perceptions" rather than actual data. In this respect it's interesting to note that transporters' opinion, which is expected to be most competent on the proveniences, is closest to the surplus ranking. Another aspect is that Nyamasheke is not mentioned at all by the operators. It may be that Karongi is accounted as source of the charcoal produced in both Districts since the route is the same. Figure 21 shows the balance map with the 4 most promising Districts according to the available surplus.

Table 27: Provenience of charcoal sold in Kigali according to transporters and retailers vis-à-vis District-wise surplus conditions

Districts	Supply/demand balance in 2009		Operators' opinion on the provenience of charcoal sold in Kigali	
		Percent of entire surplus	according to transporters (42)	according to dealer s/ retailers (105)
(decreasing surplus order)	kt od	%	%	%
NYARUGURU	**278.4**	**38.1**	29.8	21.5
NYAMAGABE	**164.7**	**22.6**	23.2	57.7
KARONGI	**93.0**	**12.7**	25.5	4.4
NYAMASHEKE	**79.5**	**10.9**		
RUTSIRO	25.5	3.5	3.4	
GAKENKE	22.2	3.0		
NGORORERO	20.6	2.8	0.4	
GISAGARA	11.2	1.5		0.7
MUHANGA	11.0	1.5	4.7	3.2
RULINDO	9.1	1.2		
KAMONYI	9.0	1.2		
HUYE	6.2	0.8	0.6	1.6
NYABIHU	-16.6			
NYANZA	-18.4		3.4	
BURERA	-19.9			2.0
GICUMBI	-26.5		2.2	8.6
RUSIZI	-29.0			
RUHANGO	-30.6		5.9	
KAYONZA	-31.4		0.4	0.3
NYAGATARE	-35.6			
GATSIBO	-38.8			
BUGESERA	-42.1			
RWAMAGANA	-43.5			
NGOMA	-46.7			
KIREHE	-51.4			
MUSANZE	-64.6			
RUBAVU	-91.1			
NYARUGENGE	-296.8			
KICUKIRO	-310.7			
GASABO	-406.2		0.4	
	-870	**100**	**100**	**100**

Figure 21: Districts ranking larger surplus conditions that have best potential for the supply of woodfuels to Kigali, supposing a 'medium' productivity of the woody biomass present (2009).



2.3.2 2020 BALANCE SCENARIOS

The 2020 scenarios hereafter discussed are based on the combination of three main components:

- Changes on woodfuels consumption/production patterns
- Changes on woody biomass productivity
- Changes of plantation areas and of tree cover in farmlands

For the first component (woodfuels consumption/production), two scenarios are considered:

1. Business-as-usual (BAU) demand scenario, reflecting the consumption pattern of 2009 in terms of conversion efficiencies (cookstoves and charcoal production) and fuel saturations in urban and rural areas, as they appear "physiologic" due to economic growth.
2. Ameliorated (AME) demand scenario, reflecting a clear change from the 2009 consumption pattern, including improved conversion efficiencies (strong dissemination of improved cookstoves and widespread adoption of efficient charcoal production systems) and marked increase of LPG use in urban areas as result of coordinated energy policies.

For the second component (woody biomass productivity) three growth variants are considered:

1. Low productivity variant
2. Medium productivity variant
3. High productivity variant

We know that the Low and the High productivity variant do exist, as described by the limited plantation growth data (see Supply Module details), but we don't know in what proportions they occur. For this, an intermediate growth level has been defined, called Medium Productivity variant, which is assumed to be realistic for the estimation of the sustainable supply potential over large areas.

The third component refers to the new tree cover that needs to be created in order to achieve a sufficient woody biomass supply capacity able to satisfy the demand in 2020. This includes tree cover in all of its forms, including conventional forest plantations, private woodlots of any size, tree lines and hedges, individual farm trees in agro-forestry systems. The Baseline 2020 scenario is characterized by BAU demand, Medium productivity variant and the plantation area of 2009 increased with 10%.

It is extremely difficult to say what will be the effect of protracted annual deficit conditions on plantation area and growth capacity. Most of the productive resource base is made by private eucalyptus plantations and it's difficult to believe that the planted area will be reduced.

It is in fact likely that, given the increasing demand and market value of woodfuels, there will be a mix of forest degradation due to overexploitation (particularly in public plantations) combined with an adequate spontaneous increment of planted trees.

Degradation and deforestation are often indicated as the inevitable effect of unsustainable woodfuels consumption, but these processes are not as widespread as one may expect. In fact, the landscape does not give the impression of being progressively degraded. This puzzle will be resolved only through detailed forest inventory and consistent land cover monitoring analyses.

For the scope of the present analysis we shall estimate what should be the intervention, such as planting efforts, agro-forestry schemes, improved charcoal making, LPG subsidies, etc.. that will satisfy the 2020 demand assuming various productivity variants.

Table 28 provides an overview of the main balance scenarios assuming a stable forest area (2009 + 10%) and BAU-AME consumption scenarios, which allows to visualize the context and to set the target of the actions between now and 2020. According to the Medium productivity and BAU demand, the balance in 2020 will show a deficit of 2.1 million tons of woody biomass, which represents approximately 36% of the expected national demand.

Table 28: Supply/demand balance conditions in 2020 assuming BAU and AME demand scenarios and Low, Medium and High productivity variants.

Values: kt od/yr		**2020 Supply potential** (Plant. area + 10%)	**2020 Demand BAU scenario**	**2020 Demand AME scenario**	**Balance 2020 BAU Demand scenario**	**Balance 2020 AME Demand scenario**
Productivity variant	Low productivity	2,533	5,547	4,254	-3,014	-1,721
	Medium productivity	**3,590**	**5,700**	4,410	**-2,110**	-820
	High productivity	4,650	5,845	4,542	-1,195	108

Note: the Demand considered is limited to conventional woody biomass used as fuelwood, wood-for-charcoal and construction material, excluding marginal woody biomass used as fuel by rural households in wood-scarce areas.

In rural areas, part of this deficit will probably be absorbed by agro-forestry products that are not entirely included in the counting of supply potential, as discussed above. However, the land resource is what it is while population grows faster than the penetration rates of alternative fuels. The demand for woodfuels will certainly grow and if no actions are taken to improve the supply potential and/or reduce the woodfuels demand the gap will be considerable.

2.4 WHAT COULD BE DONE TO FILL IN THE GAP BY 2020 ?

The "package" of interventions presented within AME scenario is not the only possible solution since it doesn't include all lines of interventions. As a matter of fact, the AME scenario does not include the impact of additional plantations nor the planting of more trees through agro-forestry programs. It is in fact recommended that the final planning of remedial actions be locally tailored, selecting from the folder of all possible solutions/interventions, those that are best adapted to local conditions and needs. Cost-efficiency and interactions among interventions must be carefully evaluated and assessing the efficiency of each line of interventions in filling in the deficit of 2.1 million tons expected in 2020, appears as an important first step.

In order to provide some insight into the possible lines of intervention, this section presents the main operational alternatives to reduce demand and/or increase supply that could contribute to resolve the gap of 2.1 million tons by 2020. Keeping the gap of 2.1 million tons as target of possible future actions, a wide range of specific interventions in the demand and supply sectors were considered and their individual contributions to the resolution of the gap by 2020 were estimated. The impact of each action is self-contained, keeping unchanged all other factors. This is meant to facilitate the evaluation of the actual efficiency of each intervention. It should be emphasized that the contribution of the various actions cannot be added up directly, since they may interact. The interventions considered are:

- further penetration of improved stoves;
- more efficient charcoal making;
- promotion of LPG in urban areas;
- better management of existing forests;
- creation of new plantations;
- promote planting in farmlands and agro-forestry.

This list is not exhaustive. There are other actions, such as the promotion of biogas, that deserve due attention and that in time will grow as true fuel alternatives. The selection has gone towards the interventions whose impact is likely to be strong enough in the 2020 timeframe.

2.4.1 Further penetration of improved stoves

The dissemination of improved stoves has a long history in Rwanda and the current penetration is quite high, ranging from 50 to 70 %, depending on the sources. The savings of wood by improved stoves varies with the stove type considered but there seems to be a reasonable agreement around 23% for fuelwood stoves and 23-26% for charcoal stoves (BEST, 2009; AESG/EWSA, 2012).

Considering a 30% increase in the penetration rate as target of this action, which would bring the penetration of improved stoves close to saturation in both rural and urban areas, the overall saving of wood would be 477 thousand tons, or 22.6 % of the 2.1 million tons gap, as shown in Table 29.

From a pure wood-saving perspective, the benefit of a massive stove dissemination program such as the one envisaged here does not appear very substantial. However, due consideration must be given to the betterment to air and health conditions that these stoves bring into poor households. Some of the improved stoves currently in use appear marginally more efficient than the three-stone system and therefore there might be significant benefit for the households, as well as for the woodfuels balance, in re-launching stove substitution programs with more efficient stove models.

Table 29: Expected impact of further penetration of improved stoves on the probable 2020 woodfuel gap of 2.1 million tons

Context	Factors subject to change / Unit	2009	2020 BAU scenario	Potential improvement by 2020	Estimated impact of each improved item in isolation		Main assumptions
					t od of wood saved	% of the gap	**Gap of 2.1 million t od of wood in 2020 BAU scenario, medium productivity variant**
	Improved Fuelwood stoves						
Rural	stove penetration (%)	50-60	50-60	80-90			BEST indicated the penetration to 50% but AESG/EWSA 2012 value is close to 70%. Assumed 23% savings of wood consumption (BEST and confirmed by average saving of improved stoves by AESG/EWSA with wide variations (5-40%) among stove types)
	Household (HH) Fuelwood consumption od kt	2,802	3,523	3,255	268	12.7	
Urban	penetration (%)	50-60	50-60	80-90			
	HH Fuelwood consumption od kt	189	288	265	23	1.1	
	Improved Charcoal stoves						
Rural	penetration (%)	60-70	60-70	90-100			Assumed 23% savings of wood consumption (BEST). Average saving of improved charcoal stoves by AESG/EWSA cooking test indicates 25.7% (15-33% depending on stove types), which may increase slightly the impact of the increased penetration.
	HH Charcoal consumption od t wood eq.	377	704	649	55	2.6	
Urban	penetration (%)	77	77	100			
	HH Charcoal consumption od t wood eq.	1,060	1,663	1,532	131	6.2	
					477	**22.6**	

2.4.2 More efficient charcoal making

Raising the yield of charcoal production from the current 12% to 18% is certainly an ambitious target, but from a technical point of view this seems to be realistic (Kammen and Lew, 1995; BEST; Murererehe, personal communication) until new scientific evidence is available. The issue, however, is that the reason for the current poor performance of charcoal yields is in good part due to the rigidity and cost of the authorization process, which induce many wood owners to opt for clandestine tree cutting and charcoal production, or simply to act too fast[22]. Speeding up the charring process because of clandestine condition (or because the permit lasts one month only) often implies the use of green wood and has a negative impact on the yield and the quality of the charcoal produced, no matter what technique is used.

Hence, the promotion of efficient charcoal making techniques must proceed hand-in-hand with the setting of friendly regulations and permit systems favoring sustainable charcoal production and encouraging the adoption of modern techniques. Improved charcoal making should receive highest attention in the wood energy strategy, given the promising saving of wood (845 thousand tons) and hence the substantial contribution to filling of the 2020 deficit (40 %), as shown in Table 30, and the fact of consolidating in this way employment and revenue in poor rural areas.

Table 30: Expected impact of <u>more efficient charcoal making</u> on the probable 2020 woodfuel gap of 2.1 million tons

Context	Factors subject to change / Unit	2009	2020 BAU scenario	Potential improvement by 2020	Estimated impact of each improved item in isolation		Main assumptions
					kt od of wood saved	% of the gap	**Gap of 2.1 million t od of wood in 2020 BAU scenario, medium productivity variant**
Rural consumers	Charcoal consumption (household (HH) + commercial) kt	55	103	103			In the absence of solid references on the current carbonisation rates, the value of 12% has been considered representative of the current situation (Kammen and Lew, 1995;BEST; Murererehe pers. comm.). 18% has been considered feasible target as result of a series of actions aiming at rationalizing and improving the efficiency of charcoal making between now and 2020. Adequate field measurements are strongly recommended to confirm/revise these preliminary values.
	charcoal/air dry wood rate	12%	12%	18%			
	od kt wood eq.	37	704	470	235	11.1	
Urban consumers	Charcoal consumption (HH + commercial) kt	171	268	268			
	charcoal/air dry wood rate	12%	12%	18%			
	od kt wood eq.	1,166	1,830	1,220	610	28.9	
					845	**40**	

[22] See section: "Administrative requirement and taxation for harvesting, charcoal production and transportation" in ANNEX 5: "Value chains of charcoal and fuelwood traded in Kigali and in other main urban areas"

2.4.3 Promotion of LPG in urban areas

The penetration of LPG in Kigali is increasing fast, in line with economic growth of wealthier urban households. According to major distributors, the penetration will keep on growing but it is unlikely that the penetration of LPG will exceed 15% of Kigali households in 2020 without subsidies or other price-constraint systems (unless international oil price fluctuations modify the situation entirely).

LPG is seen as a viable alternative to charcoal in urban areas in the context of Vision 2020 and within the Energy Sector Strategic Plan (ESSP) 2012-2017. The hypothesis here considered foresees the increase of LPG penetration up to 4 times the current level in Kigali and in other urban areas; this means that up to 30 % and 10 % of all households are expected to use LPG in 2020 respectively. This level of substitution of charcoal would bring a saving of 232 thousand tons of wood (with respect to the BAU scenario) and the filling of 11% of the 2020 gap, as shown in Table 31.

Not a major impact and not necessarily a lasting one either. Experience in various Sub-Sahara countries shows that subsidized fuels rarely produce a sustainable impact. Many households revert back to charcoal when subsidies cease and the price of LPG increases (Owen et al., 2012).

Table 31: Expected impact of promotion of LPG in urban areas on the probable 2020 woodfuel gap of 2.1 million tons

Context	Factors subject to change / Unit	2009	2020 BAU scenario	Potential improvement by 2020	Estimated impact of each improved item in isolation		Main assumptions
					kt od of wood saved	% of the gap	**Gap of 2.1 million t od of wood in 2020 BAU scenario, medium productivity variant**
Kigali	LPG penetration (%) in urban households (HH)	7.6	15	30			LPG penetration is very recent and increasing fast. The increase of LPG penetration to 15% of the households in Kigali (and 4% in other urban areas) is considered "physiologic" under current economic growth. The doubling of LPG penetration to 30% in Kigali (and 10% in other urban areas) is tentatively set as a realistic target if appropriate subsidy policies are put in place.
	Charcoal and Fuelwood consumption by urban HH (od t wood eq.)	885	1,275	1,084	191	9.1	
Other urban areas	LPG penetration (%) in urban HH	2.9	4	10			
	Charcoal and Fuelwood consumption by urban HH (od t wood eq.)	364	677	636	41	1.9	
					232	**11.0**	

2.4.4 Better management of existing forests

The management of forest resources in Rwanda has a great potential because the ecological characteristics are in general suitable for forest plantations, because private landowners recognize the economic value of plantations and planting trees has become part of farm management practices, and because forest management has been virtually absent, so far.

A lot can be done in forest management and most actions should be in support of plantation forestry in private and public lands. As in the case of charcoal making, the action must be oriented towards enabling framework conditions, such as governance, taxation and regulation, as well as towards silvicultural support. It must be emphasized that a detailed inventory of forest resources is a fundamental pre-requisite to improved forest management in Rwanda.

The increase in productivity of existing plantation area, here considered, would be the end result of a wide series of silvicultural actions that include, among others: farmers access to optimal genetic resources and support in the selection of suitable species; training on good nursery, planting and maintenance practices; farmers access to fertilizers needed to integrate soil nutrients; clear prescriptions and training on felling practices; optimized rotation systems oriented to the production of the required wood assortments; etc.

It is estimated that the augmented productivity of existing plantations (including a 10 % increase in plantation area between 2009 and 2020) will increase the national supply potential with892 thousand tons, or 42 % of the 2020 gap, as shown in Table 32. It is unlikely that this increment of production be reached entirely by 2020, as 8 years is a too short timeframe in forestry, but it shows the great potential of good forest management and helps to visualize the challenge of forestry planning in Rwanda.

Table 32: Expected impact of <u>better management of existing forests</u> on the probable 2020 woodfuel gap of 2.1 million tons

Factors subject to change / Unit	2009	2020 BAU scenario	Potential improvement by 2020	Estimated impact of each improved item in isolation		Main assumptions
				kt od of wood saved	% of the gap	**Gap of 2.1 million t od of wood in 2020 BAU scenario**
Plantation productivity (average) od t/ha/yr	9.5	9.5	12.4			2009: 279,967 ha of productive plantations, Medium productivity variant (midrange of ISAR and SEW/IFDC MAI values).
Plantation area (productive) '000 ha	280	308	308			2020 BAU: Medium plantation productivity increased with 10% (+ 10% increase in plantation area between 2009-2020)
Plantation Medium productivity od kt	2,649	2,914	3,806	**892**	**42.3**	2020 Managed scenario: same planted area of 2020 BAU but High productivity (SEW/IFDC MAI values).

2.4.5 Creation of new plantations

The creation of new plantations to achieve a national of tree/forest cover of 30% is envisioned in forestry policy papers, with particular attention to steep slopes areas in order to combine protective and productive functions. But Rwanda is an intensely farmed country and finding suitable areas for new forest plantations is not simple matter. In fact, it appears that the creation of conventional plantations is more feasible in the eastern regions of the Country where the land use is less intensive.

While the analysis of steep slope area potentially available and the difficulty of identifying available plantation areas is discussed in Annex 4, we are here simulating the impact of the establishment of new plantation areas, wherever these may be established. In order to be realistic, we considered a more achievable scenario of 30 thousand hectares and a more ambitious scenario of 50 thousand hectares.

In the hypothesis of 30 thousand hectares of new plantations the contribution in filling the 2020 gap would be 13.5 %, assuming medium productivity, or up to 17.6 %, assuming high productivity, as shown in Table 33. In the hypothesis of 50 thousand hectares, the contribution in filling the 2020 gap would be between 22.4 and 29.3 %, depending on the assumed annual productivity (Table 32).

To be noted that the plantation area theoretically needed to fill in the gap entirely, assuming medium productivity, would be 223 thousand hectares, which is clearly an impossible target.

Table 33: Expected impact of creation of new plantations on the probable 2020 woodfuel gap of 2.1 million tons

Context	Factors subject to change / Unit	2009	2020 BAU scenario	Potential improvement by 2020	Estimated impact of each improved item in isolation		Main assumptions
					kt od of wood saved	% of the gap	**Gap of 2.1 million tod of wood in 2020 BAU scenario**
	Creation of new plantations over 30,000 ha						
							30,000 ha of new plantations
Medium productivity	Productivity/ha (Medium)			9.46			Case 1: Medium productivity assumed for al new plantations
	Total annual productivity kt od			284	284	13.5	
High productivity	Productivity/ha (Medium)			12.36			Case 2: High productivity assumed for al new plantations
	Total annual productivity kt od			371	371	17.6	
	Creation of new plantations over 50,000 ha						
							50,000 ha of new Plantations
Medium productivity	Productivity/ha (High)			9.46			Case 1: Medium productivity assumed for al new plantations
	Tot annual productivity kt od			473	473	22.4	
High productivity	Productivity/ha (High)			12.36			Case 2: High productivity assumed for al new plantations
	Tot annual productivity kt od			6181	6181	29.3	

2.4.6 Tree planting in farmlands and agro-forestry

The role of individual farm trees and small woodlots below 0.25 hectares (limit of plantation size in the current forest map) in providing woody biomass for energy and other uses is important, although their quantitative contribution is not yet well defined. The current contribution by trees and shrubs in farmlands is conservatively estimated at 611 thousand tons per year. The increase of tree cover of adequate species would considerably contribute to the energy need of rural households as well as to provide small income in case of needs, as farmers know very well.

In order to define meaningful targets for agro-forestry programs, the contribution of hypothetical increments of tree cover in farm areas of 3 % and 5.2 % of non-forest land area are considered. In the first case the current trees and shrubs cover, estimated to be 5.2 %, should be increased to 8.2 % through tree planting, individually or as micro woodlots. This would produce an estimated additional woody biomass supply of 619 thousand tons, or 29.3 % of the 2020 gap, as shown in Table 34. In the second case the current cover is doubled to 10.4 % , with an estimated additional woody biomass supply of 1.07 million tons, or 50.8 % of the 2020 gap.

It should be noted, however, that the real contribution of TOF and agro-forestry to fuelwood supply is not documented. The productivity values applied in these estimates are based on MAI values of plantations and do not consider annual pruning and other farm practices. Therefore, these values may underestimate the real productivity.

Table 34: Expected impact of tree planting in farmlands and agro-forestry on the probable 2020 woodfuel gap of 2.1 million tons

Context	Factors subject to change / Unit	2009	2020 BAU scenario	Potential improvement by 2020	Estimated impact of each improved item in isolation		Main assumptions
					kt od of wood saved	% of the gap	**Gap of 2.1 million t od of wood in 2020 BAU scenario, medium productivity variant**
3 % extra tree cover							Case 1: TOF cover increased of 3%: increment of current trees cover in farm areas of 3% (from 5.2 to 8.2%) Case 2: TOF cover doubled: increment of current trees and shrub cover in farm areas of 5.2% (from 5.2 to 10.4%) **Note:** The real contribution of TOF and agro-forestry to fuelwood supply is not documented. The values are based on MAI of plantations and do not consider annual pruning and other farm practices. **These values may underestimate the real productivity.**
	% of TOF cover	5.2	5.2	8.2			
	Tot productivity kt od	611	611	1,230	619	29.3	
5.2% extra tree cover							
	% of TOF cover	5.2	5.2	10.4			
	Tot productivity kt od	611	611	1,684	1,073	50.8	

2.4.7 Pooling of interventions

Table 35 provides an overview of the interventions considered and proposes a possible blending for the filling of the expected 2020 supply/demand balance gap. This is here presented as general country-wide guideline, while the specific interventions must be locally tailored, as discussed in the Section 1.3.3 "Recommended District-level interventions aiming at sustainable wood energy by 2020" in the previous Chapter.

Table 35: Review of various lines of interventions and presentation of one possible combination aiming at the filling of the estimated 2020 woodfuel gap of 2.1 million tons

Production/ consumption parameter	Potential impact on individual basis	Pros and Cons	Possible "blending" of interventions by 2020	
	% of 2.1 Mt gap filling		**% of 2.1 Mt gap filling**	**Objectives and remarks**
Improved stoves →+30%	**22.6 %**	**Pros:** Improved indoor air quality and health **Cons:** Huge program with relatively limited impact	**15 %**	20% additional penetration. Concentrate on charcoal stoves in urban areas and on fuelwood stoves in rural areas
More efficient charcoal making 12% →18%	**40.0 %**	**Pros:** Substantial impact; Consolidation of income and employment in rural areas **Cons**: Must proceed in combination with forest management	**30 %**	Focus on 75% of charcoal production in Nyaruguru, Nyamagabe, Nyamasheke and Karongi, Districts. Create favorable tax & permit system rewarding efficiency and sustainability; promote cooperatives of producers.
Promotion of LPG in urban areas	**11.0 %**	**Pros:** Rapid response **Cons:** Limited impact; non-renewable; requiring subsidies on imported oil products; uncertainty on the economic sustainability; risk of return to charcoal when subsidies cease.		LPG use will "naturally" increase in wealthier urban households. It seems preferable to promote biogas in rural areas and in all suitable situations instead.
Better management of existing forests	**42.3 %**	**Pros:** Substantial impact; consolidation of income and employment in rural areas. **Cons:** Relatively slow impact	**20 %**	Improved management over 150,000 ha. Supporting private and public forestry has paramount importance; the inventory of biomass resource is a pre-requisite; priority areas are charcoal production sites
Creation of 30,000 ha of new plantations	**13.5 - 17.6%**	**Pros:** Soil protection in steep slope areas; increased supply in forest-poor areas **Cons:** Difficulty to find suitable plantation areas; impact rather limited and relatively slow	**15 %**	Establishment of approx. 30 thousand ha in deficit areas in Eastern and Northern provinces and in steep slope areas, if feasible according to land use and ownership.
Creation of 50,000 ha of new plantations	**22.4 - 29.3%**			
Agro-forestry (3% extra tree cover)	**29.3 %**	**Pros:** Soil protection in steep slope areas where plantations are not feasible; increased supply in forest-poor areas; substantial impact **Cons:** Very diffuse action; difficulty to quantify the impact	**20 %**	Create 2% extra tree cover in rural areas. Support coping strategies undertaken by farmers; promote planting of trees and woodlots from good seeds in farmlands. Priority areas: deficit areas of Eastern province and on steep slopes of Northern, Southern and Western provinces
Agro-forestry (doubling of tree cover)	**50.8 %**			
			100 %	

2.5 MAIN CONCLUSIONS OF WISDOM ANALYSIS

2.5.1 Comparing WISDOM analyses

A comparison of the new updated and upgraded WISDOM analysis with the previous one, carried out by FAO/NAFA in 2009-2010 shows the paramount role of reference data. The results of the two studies are significantly diverse, due to the many differences in source data that characterize the two studies. In fact, the two efforts must be seen as progressive stages of understanding the woodfuels demand and supply potential in Rwanda based on improved reference data. In order to describe the structural differences between the two studies, Table 36 shows their distinct analytical features and reference sources.

Table 36: Key features of the WISDOM analyses carried out by FAO/NAFA (2009) and by PAREF B2/DFNC (2912).

	WISDOM FAO/NAFA (2009)	WISDOM PAREF B2/DFNC (2012)
Reference years of analysis	2006	2009 and 2020
Demand Module references		
Population	8,910,700	10,432,000 (2009) 14,079,058 (2020)
Household consumption	BEST 2009; EICV2	Own survey in urban areas; EICV3 2010; DHS Surveys; BEST 2009 and MININFRA data
Total Demand (kt od)	**2,974** (2006)	**4,197** (2009, revised rural demand)
Supply Module references		
Forest map	CGIS/ISAR 2007 (source: satellite data 2004 approx.)	CGIS/PAREF 2012 (source: orthophoto 2008-2010)
Plantation area ('000 ha)	**114**	**286.8**
Plantation productivity	ISAR 2007	ISAR 2007; IFDC/SEW Survey 2012
Total available supply potential (kt od)	**1,119** (2006, BAU variant)	**3,327** (2009, Medium productivity)
Supply/Demand Balance (kt od)	**-1,827**	**- 870** (2009) **-2,110** (2020, BAU scenario)

The conclusion is that the results of the two studies cannot be directly compared. Most important, the differences between them should not be considered as changes in the wood energy sector or trends but rather as progressive stages of understanding of the situation based on improved reference data.

Among many small differences and refinements of parameters, the most relevant one is the new plantation area: the forest map of CGIS/ISAR 2007 based on satellite data of 2004 showed a plantation area of 114,000 ha, while the new forest map by GCIS/PAREF 2012 based on high-resolution aerial photography of 2008-10 shows a plantation area of 286,800 ha (i.e. an "apparent" increment of 250 % !). This obviously provoked a true revolution in the WISDOM analysis of the supply potential, and, most relevant, shows that the land use of Rwanda requires a very high spatial resolution of analysis. On the other hand, these differences show how dynamic the Country is in producing reference data useful to planning and policy formulation.

2.5.2 Recommendations on the wood energy knowledge base and the appropriation of the WISDOM tool

- The development of WISDOM Rwanda implied several assumptions and some tentative value attributions to fill in for information gaps. In order to improve and consolidate the knowledge base these assumption need validation and tentative estimates should be replaced by solid reference data. The most relevant information gaps to be filled in with priority include the following:
- **Concerning the Demand Module:**
    - What sort of fuelwood use rural households in forest-poor areas? Fuelwood made of stem wood and branches is included in forest productivity but twigs and pruned branches are not included in conventional forest productivity and should be accounted separately, otherwise the pressure on forest resources may be exaggerated.
    - In view of the above, it is recommended to assess the fraction of rural fuelwood consumption that is satisfied by "marginal" wood assortments (twigs, deadwood, annual and periodic pruning of farm trees and shrubs, etc.) and by other farm residues. This should be done through a well-focused field survey, stratified on the basis of the rural fuelwood balance map. Scope of such survey must be the accurate description and weighting of the fuelwood used by households on a daily basis, privileging the accuracy of measurement rather than the number of observations.
    - The fuelwood and charcoal consumption in the commercial sector is quite relevant but available data is incomplete and not conclusive.
    - What is the real consumption for brick making? The estimated consumption is tentative and no trends scenarios could be formulated. Since District authorities are now collecting brick production records for taxation purposes it will be possible to assess with precision the quantities produced and their distribution. Per-unit consumption rates of sawmill residues, fuelwood and other fuels should then be estimated in order to estimate the fuel demand and its distribution.
    - Scientific data on current charcoal yields is missing. In order to assess with accuracy the volume of woody currently used in charcoal production and to estimate the benefits of modern carbonization technologies the survey of current charcoal production is recommended.
- **Concerning the Supply Module:**
    - Due to limited available references, wide assumptions have been made in this study in the attempt of defining a meaningful estimation of the real sustainable supply potential. Rather than further speculations is now time to proceed with well-designed nation-wide inventories of all biomass sources specifically focused on their sustainable growth potential.
    - It is generally acknowledged that trees outside forest (TOF) and agro-forestry in general play an important role in the supply of cooking fuels to rural household, but there is no data. The productivity of trees outside forest is here tentatively estimated with reference to plantation data, rather than to agro-forestry practices, due to the absence of reference data.
    - It is essential to assess the sustainable production potential of trees outside forest and micro-woodlots in farmlands and agro-forestry systems.
    - It is recommended that the forthcoming forest inventory includes a component aiming at farmlands and agro-forestry systems, in order to assess the production potential of "conventional" wood from trees outside forest and micro-woodlots as well as "marginal" wood assortments (twigs, deadwood, annual and periodic pruning of farm trees and

shrubs, etc.).

- In the national debate the use of woodfuels is often deemed responsible for deforestation and forest degradation, although there is no clear evidence of such impact. In order to clarify this issue it is recommended to carry out a land cover monitoring analysis to assess objectively IF and WHERE and HOW MUCH deforestation and degradation processes do occur in Rwanda.
    - The study should be designed with the objective of determining the cause-effect mechanisms, in addition to simple change rates, in order to document to which extent woodfuels production is a driving cause.
    - Given the intensity of land use and the small size of forest areas, it is suggested to use high-resolution multi-temporal data, such as the 2009 orthophoto coverage coupled by high-resolution satellite data (i.e. Quickbird or similar) and to apply a systematic sampling approach rather than wall-to-wall.
    - In order to assure the consistency of observations that is fundamental in land cover monitoring, it is recommended to apply the inter-dependent interpretation procedures (FAO 1996), adequately adapted to on-screen interpretation of digital data.
    - The analysis should also serve to review/validate the new CGIS Forest Map.

2.5.2.1 Appropriation by DFNC of WISDOM tool

- The WISDOM Geo-database and the necessary software are installed on DFNC computers. The training in handling WISDOM geo-database was delivered, aiming at enabling the DFNC trainee in using Arc Catalog, Arc Map and some geoprocessing tools. This may be adequate for simple consultation of thematic layers and extraction of data at the chosen level of reporting, but not for maintenance and updating of WISDOM parameters. For this purpose a more advanced training in spatial analysis and geo-statistical analysis is strongly recommended.
- The full appropriation by DFNC of the WISDOM geo-database as a tool to support decision and policy making, in order to be effective, requires the appointment of one professional officer with specific responsibilities on this task and with adequate GIS competence, which is at present not available.
- For the time being, it is recommended to develop strong synergies between DFNC and the Department of Lands (DL), within RNRA. DL, with its GIS capacities can operate on the WISDOM geo-database while DFNC staff can define the scope of the analysis to be conducted and provide details on the technical parameters (inventory results, new consumption data, etc.). In order to provide on-job training on the GIS component of WISDOM analysis to DFNC staff, it appears more efficient if the designated DFNC professional do operate in DL settings.

3. WOODFUELS VALUE CHAIN

3.1 ECONOMIC MAGNITUDE OF FUELWOOD AND CHARCOAL TRADING

The value of the charcoal market of Rwanda in 2009 may be estimated at 37.9 billion RWF at current market price[23], with 22.3 billion RWF in the urban area of Kigali alone, as shown in Table 37. These values are based on the assumption that all charcoal supply is market-based. This is certainly true for the charcoal consumed in Kigali and in other major towns, though rural charcoal is partially self-produced or otherwise informally procured and therefore only partially enters the market cycle. District-wise values of the charcoal market are shown in Annex 5, Table A5.15.

Table 37: Province-wise market value of charcoal trade in 2009 and in 2020 according to BAU and AME scenarios (applying current charcoal retail practiced in Kigali and in other urban areas).

	Charcoal trade 2009			Charcoal trade 2020 - BAU			Charcoal trade 2020 - AME		
	Rural	Urban	Total	Rural	Urban	Total	Rural	Urban	Total
Province	Million RWF			Million RWF			Million RWF		
Kigali City	1,923	22,288	24,212	2,331	32,659	34,990	2,149	26,612	28,761
Southern	1,016	3,487	4,502	1,767	7,635	9,401	1,629	6,632	8,262
Western	4,025	1,171	5,196	8,029	1,796	9,826	7,403	1,565	8,968
Northern	939	857	1,795	1,828	1,502	3,330	1,684	1,308	2,992
Eastern	1,628	566	2,194	3,955	1,085	5,041	3,648	945	4,594
Total Rwanda	**9,530**	**28,369**	**37,900**	**17,910**	**44,678**	**62,588**	**16,513**	**37,063**	**53,577**

More complex is to assess in monetary terms the economic magnitude of fuelwood. Fuelwood production and supply systems are in good part informal and, in addition, the market price of wood for energy use varies considerably, ranging from 2,400 RWF/stere for wood for charcoal (usually fresh wood at harvesting site), to 6000 RWF/stere for large consumers such as schools, to as much as 35,000 RWF/stere when it is sold by 15kg bundles at city markets.

Allocating a small price for non-commercial fuelwood consumed by rural households (i.e. 8 RWF/kg based on the estimated collection time; applied to 80% of the rural HH demand) and applying the commercial price for fuelwood in rural areas (500 RWF/bundle, or 11,667 RWF/stere; applied on the remaining 20% of rural HH demand); applying the commercial price of 6000 RWF per stere (17.1 RWF/kg) for the fuelwood consumed by large consumers (schools, prisons, brick makers, tea factories) and applying the commercial price of 1500RWF/bundle (or 35,000 RWF/stere) to urban households demand, the total value of fuelwood in 2009 may be quantified at 58.9 billion RWF, or 106.9 million US$. The results of this are shown in Table 38. District-wise values are shown in Annex 5, Table A5.16. Considering 2009 GDP of 5,200 Million US$, the wood energy sector contributed some 3.4 % to the national Domestic Product.

[23] The current retail price of one ton of charcoal in Kigali is 163,636 RWF, while in other major towns it is 175,000 RWF .

Table 38: Province-wise market value of fuelwood trade in 2009 and in 2020 according to BAU and AME scenarios (applying current fuelwood retail prices).

	Fuelwood trading 2009					Fw trade 2020 - BAU	Fw trade 2020 - AME
	Rural HH Non-commercial	Rural HH Commercial	Urban HH Commercial	Other uses	Total	Total	Total
Province	Million RWF					Million RWF	Million RWF
Kigali City	248	258	4,040	415	4,961	4,621	2,388
Southern	4,490	4,677	5,629	830	15,626	22,261	19,477
Western	4,715	4,912	4,161	846	14,635	18,753	16,727
Northern	3,623	3,774	3,044	909	11,352	15,040	13,400
Eastern	4,853	5,055	2,012	392	12,312	18,256	16,393
Total Rwanda	**17,930**	**18,677**	**18,886**	**3,392**	**58,885**	**78,931**	**68,386**

Note: HH = household sector; other uses includes commercial, industrial and public sectors.

3.2 *CHARCOAL VALUE CHAIN - SUMMARY OF RESULTS*

The description of the surveys carried out and detailed presentation and analysis of the value chains of charcoal and fuelwood are presented in Annex 5, which includes the following aspects:

- Production, trading and retailing organization
- Costs and profit for charcoal and fuelwood value chain
- Profile of traders and business models involved in fuelwood and charcoal trading activities
- Administrative requirement and taxation for harvesting, charcoal production and transportation
- Opportunities and threats regarding taxation strategy
- Socio-economic dimensions of fuelwood and charcoal production schemes
- Employment generated by the charcoal chain

The present section provides only a tabular presentation of costs and profits of the charcoal value chain and the analysis of the relative generation of employment. For the detailed description of each component of the value chain and the others thematic issues listed above, reference is made to Annex 5.

3.2.1 Overview of costs and profit for charcoal value chain

Table 40 presents the costs, taxes, and expenses incurred by the main actors in the charcoal value chain. The values are reported on a per-unit of product basis (one ton of charcoal) and also with reference to the total amount of charcoal consumed in Kigali and in the entire country in 2009. The results show that, assuming Medium productivity of plantations and 8 years rotations, the highest profit goes to wood producers (22.2% of market value), followed by dealers/retailers (13.3%), transporters (9.7%) and finally charcoal makers (6.8%). With shorter rotations the profit for wood producers per ton of charcoal produced would be lower but more frequent. The distribution of costs shows charcoal producers costs of 14.6% (of charcoal market value), followed by transporters (12.2%), wood producers' (10.2%) and finally dealers/retailers (1.3%).

Summarizing the value chain in Table 40 by component and by location (production or consumption area), Table 39 shows that 38.3% of the market value goes to costs, 9.7% to taxes and permits and 52% to profits. Concerning the geographic distribution, 73.4 % of charcoal market value goes to the production area and 26.6 to the consumption area[24]. Production areas get 80.6% of all costs, 90.2% of all taxes and

[24] The values relative to transporters are assumed to be divided equally between production and consumption areas.

65% of all profits. Complementarily, consumption areas get 19.4% of all costs, 9.8% of all taxes and 34.9% of all profits.

Table 39: Summary of charcoal value chain by components and area. Values are % of charcoal market value

Components	Production areas	Consumption areas	Total
Costs	30.9	7.4	**38.3**
Taxes and permits	8.7	0.9	**9.7**
Profits	33.8	18.2	**52.0**
Total	**73.4**	**26.6**	**100.0**

In addition, Table 40 provides values estimated for year 2020 according to the BAU and AME demand scenarios. To be noted that the 2020 projections are not the result of economic trends analysis (no changes are assumed for costs, prices, etc.) but simply the application of current per-unit values to the quantities that are expected to be consumed in 2020 according to the BAU and AME scenarios.

Table 40: Cost structure of the charcoal value chain in Kigali and Rwanda 2009 - 2020

	RWF/t of charcoal sold in Kigali	Fraction of market value	2009 Kigali charcoal chain		2009 Rwanda charcoal chain	2020 Rwanda charcoal chain (BAU scenario)	2020 Rwanda charcoal chain (AME scenario)
(Estimated charcoal consumption)			*(147,959 t)*		*(226,177 t)*	*(371,529 t)*	*(317,565 t)*
	RWF	**%**	**Million RWF**	**Location**	**Million RWF**	**Million RWF**	**Million RWF**
Wood production				**As per transporters:**			
Production cost for a ton of charcoal (Medium productivity; 3 rotations of 8 yrs)(including land value)	16,678	10.2	2,468	NYARUGURU 29.8%; KARONGI 25.5%;	3,772	6,197	5,296
Profit for wood producer (Medium prod. scenario) * in Low prod. = 17.6%; in High prod = 24.6%)	36,283	22.2 *	5,368	NYAMAGABE 23.2%; RUHANGO 5.9 etc...	8,206	13,480	11,522
Total wood production	52,961	**32.4**	**7,836**		**11,979**	**19,677**	**16,819**
Charcoal production	(cost 52,961)			**According to**			
Tree cutting permit paid to the production District	1,963	1.2	290	**transporters:**	444	729	623
Other taxes and royalties paid to the production District	5,510	3.4	815	NYARUGURU 29.8%; KARONGI 25.5%;	1,246	2,047	1,750
Cost for manpower needed to produce a ton of charcoal	23,864	14.6	3,531	NYAMAGABE 23.2%; RUHANGO 5.9%;	5,397	8,866	7,578
Profit for a charcoal producer	11,157	6.8	1,651	other Districts 15.6%	2,524	4,145	3,543
Total Charcoal production	42,494	**26.0**	**6,287**		**9,611**	**15,788**	**13,494**
Distribution	(cost 95,455)						
Taxes and royalties paid by distributor to District (production place) per ton	6,778	4.1	1,003	(See production Districts)	1,533	2,518	2,153
Taxes and royalties paid per ton to the District (selling)	497	0.3	74	Kigali Districts	112	185	158
Expenses for distribution other than taxes per ton	20,028	12.2	2,963	Kigali and production sites	4,530	7,441	6,360
Profit for Distributor per ton	15,878	9.7	2,349	Kigali and production sites	4,480	7,691	6,654
Total Distribution	**43,182**	**26.4**	**6,389**		**10,656**	**17,835**	**15,324**
Dealer / retailer	(cost 138,636)						
Taxes and royalties paid to District per ton	1,056	0.6	156	Kigali Districts	233	380	324
Expenses other than taxes and royalties paid per ton	2,177	1.3	322	Kigali	410	643	542
Profit for charcoal dealer per ton	21,767	13.3	3,221	Kigali markets	5,012	8,265	7,073
Total dealer/retailer	**25,000**	**15.3**	**3,699**		**5,654**	**9,288**	**7,939**
Market value of charcoal in Kigali	**163,636**	**100.0**	**24,212**		**37,900**	**62,588**	**53,577**

Note: The total values at national level keep into consideration the slightly higher retail price and distribution costs paid in other cities.

3.2.2 Overview of employment generation by the charcoal value chain

Table 41 presents a detailed estimation of the employment generated by the charcoal market in the various phases of the production, distribution and sale processes of the chain. Jobs created are expressed on a per-unit basis (one ton of charcoal) and also with reference to Kigali charcoal consumption and to the national consumption in 2009.

Employment generated by the charcoal chain is considerable. One ton of charcoal sold in the market requires 38.2 man-days of work. The Kigali charcoal market implies 5.6 million man-days of work per year which, assuming full time employment, means over 18 thousand man-years. In reality, given that many phases of the chain are part-time rather than full time engagements, it may be assumed that the Kigali charcoal market assures the livelihood, or represents the main source of the annual income, for more than 30 thousand families. Considering the estimated 27.8 thousand man-years of employment generated for the whole country, it may be assumed that the charcoal chain represents the main source of income for over 50 thousand families or approximately 2.8% of the entire population.

The largest fraction of employment is generated by charcoal production (61.8%) followed by wood production (19.2%), both located in the production areas, while distribution and selling cover 6 and 12.8% of the generated employment, respectively.

Table 41 provides also the estimated employment that would be generated in 2020 according to the BAU and AME scenarios. To be noted that the 2020 projections are simply the application of current per-unit man-days values to the quantities that are expected to be consumed in 2020 according to the BAU and AME scenarios, without speculations on how the labor market may evolve between now and 2020.

Table 41: Employment generation by the charcoal value chain in Kigali and whole Rwanda 2009 - 2020 (assuming 3 rotations of 8 years per plantation).

	Job generation			Jobs generated by 2009 Kigali charcoal chain			2009 Rwanda charcoal chain	2020 Rwanda charcoal chain (BAU)	2020 Rwanda charcoal chain (AME)
	1 ha plantation	1 ton charcoal		*Charcoal demand (t):*	*147,959*		*226,177*	*371,529*	*317,565*
	Man Days	Man Days	%	Man Days	Man years (@310 days/yr)	Location	Man years (@310 days/yr)	Man years (@310 days/yr)	Man years (@310 days/yr)
Wood production (assuming 3 rotations of 8 years)		**(Medium productivity)**							
Seedling production (1/3)	10	0.7	1.9	107,583	347	**As per transporters:** NYARUGURU 29.8%; KARONGI 25.5%; NYAMAGABE 23.2%; RUHANGO 5.9 etc...	531	871	745
Planting (1/3)	69	5.1	13.4	757,547	2,444		3,736	6,136	5,245
Maintenance after planting (1/3)	20	1.5	3.9	220,645	712		1,088	1,787	1,528
Man Days needed for wood production (Medium productivity)	**98**	**7.3**	**19.2**	**1,085,774**	**3,502**		**5,354**	**8,795**	**7,517**
Charcoal production									
Cutting trees/packing		6.3	16.4	924,932	2,984	**According to transporters:** NYARUGURU 29.8%; KARONGI 25.5%; NYAMAGABE 23.2%; RUHANGO 5.9%; other Districts 15.6%	4,561	7,492	6,404
Kiln set-up and keeping		3.0	7.9	446,628	1,441		2,202	3,618	3,092
Drawing charcoal from the kiln		1.2	3.2	181,856	587		897	1,473	1,259
Cooling charcoal		0.8	2.1	119,250	385		588	966	826
Charcoal collecting		4.6	12.0	677,861	2,187		3,343	5,491	4,693
Bags loading		2.3	6.0	339,862	1,096		1,676	2,753	2,353
Transporting Bags to road side		5.4	14.2	798,974	2,577		3,940	6,472	5,532
Total Charcoal production		**23.6**	**61.8**	**3,489,363**	**11,256**		**17,206**	**28,264**	**24,159**
Distribution									
Loading and unloading		1.5	3.9	219,625	708	Kigali and production sites	1,083	1,779	1,521
Transportation		0.9	2.3	127,974	413		631	1,037	886
Total Distribution		**2.3**	**6.2**	**347,599**	**1,121**		**1,714**	**2,816**	**2,407**
Dealer / retailer		**4.9**	**12.8**	**723,335**	**2,333**	Kigali Districts	**3,567**	**5,859**	**5,008**
Total charcoal chain		**38.2**	**100.0**	**5,646,071**	**18,213**		**27,841**	**45,734**	**39,091**

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ANNEXES

ANNEX 1: URBAN HOUSEHOLDS CONSUMPTION SURVEY IN THE CITY OF KIGALI AND OTHER CITIES

Urban household sample design.

As originally planned, 432 households were selected randomly in three Districts of Kigali City and 289 households in other important urban areas, with a final selection of Ruhengeri in Musanze District, Gisenyi in Rubavu District, Rwamagana in Rwamagana District and Butare in Huye District, in order to represent all other provinces of Rwanda.

One specific scope of the survey was to produce quantitative household consumption values of fuelwood and charcoal, for which the "average day" approach was followed (FAO 2002). In practice, this meant the quantity of fuelwood or charcoal that the household member physically extracted from his stock as the amount used in a normal day was weighted and recorded.

Sample distribution.

The distribution of the sample within Kigali and the other towns has been organised in such a way as to adequately represent the full range of socio-economic conditions. This was done applying three strata relative to the density of housing, which has been taken as an indicator of the income level of households and of potentially different fuel consumption patterns. The stratification was done through interpretation of the orthophoto covering the cities, with additional support from Google Earth. The data layers used include:

- Administrative map of Cells (subdivisions of Sectors). Kigali city is thus divided into 65 Cells.
- Orthophoto-based Land Cover map limited to the "build up" class, used to outline the urbanized areas within the Cells. In addition, areas supposed to be non-residential (areas covered by schools, commercial buildings, official facilities) were not considered. In this regard, the layer "built-up" has been overlaid to the orthophoto for better interpretation of what may be qualified as residential urban areas.
- In each urban administrative Cell, three categories of housing systems were identified: sparse, medium and dense housing. Within the Cell, a percentage of each category was assigned based on the interpretation of the quality of the housing as seen on orthophotos. Figure A1.2 shows examples of the three housing typologies, as well as the results of the stratification for Kigali.

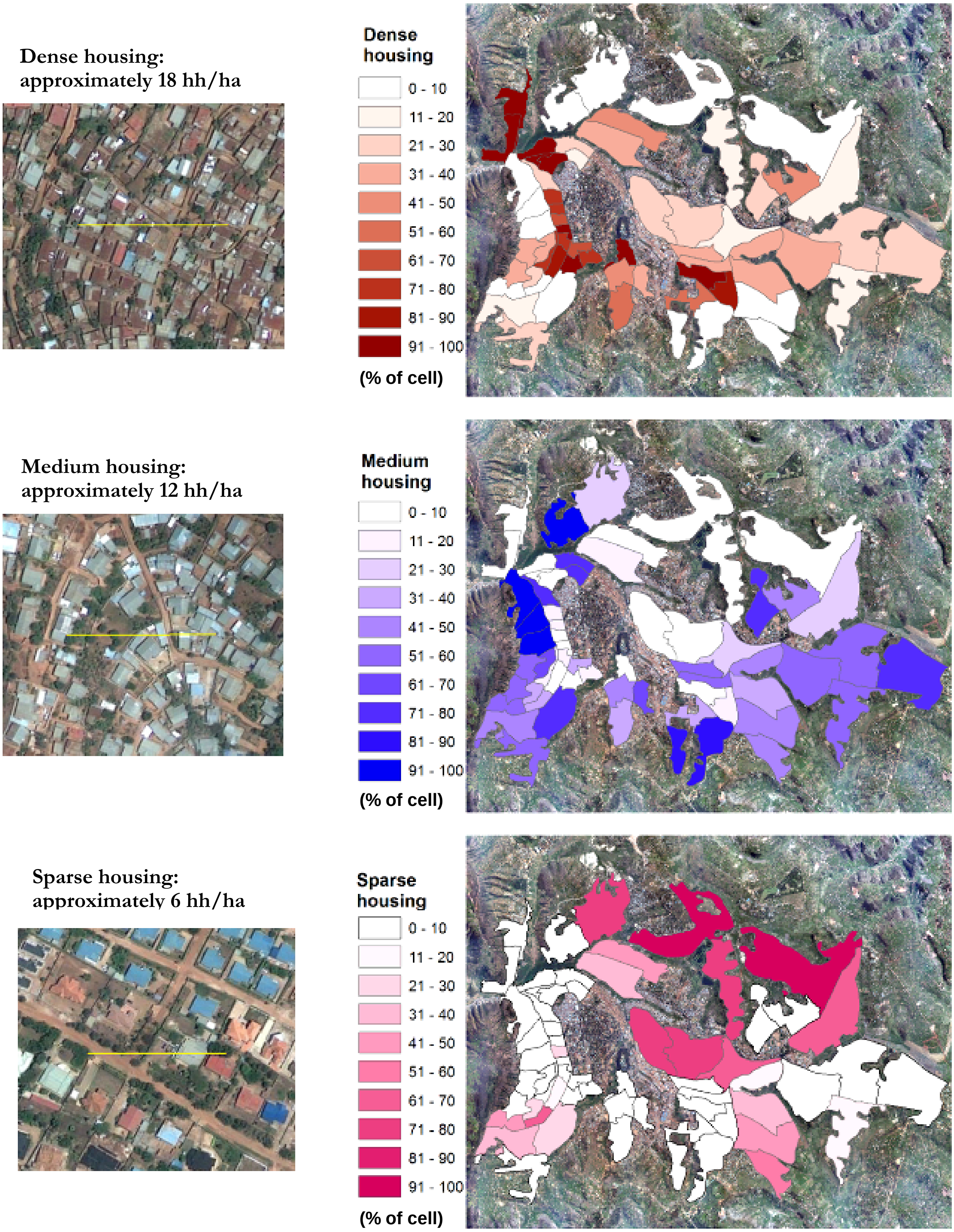
Figure A1.1: Orthophoto coverage and outline of the urban area of Kigali.

Keeping constant the total number of sample units in Kigali (432 households), the number of households to be interviewed in each strata was determined proportionally to the number of households estimated for the strata and thus proportional, at least indicatively, to the number of households in the different income levels. The number of households to be interviewed was calculated as follows:

- Calculating the total area of urban Cell;
- Calculating areas of each housing category based on the percentage assigned to each housing typology;
- Calculating number of households of each category considering 18 households/ha in dense housing, 12 households / ha in medium and 6 households/ha in sparse housing

- Calculating the proportions of households to be sampled per category.

Figure A1.2: Stratification of Kigali residential areas according to housing density



In other cities the same methodology was applied to select 289 households in the following cities: Ruhengeri in Musanze District, Gisenyi in Rubavu District, Rwamagana in Rwamagana District and Butare in Huye District. Table A1.1 summarizes the sample distribution by housing system in Kigali as well as in other selected urban areas.

It is to be highlighted, however, that the urban context represented by this survey does not correspond with the "urban" population defined by NISR in the 2002 census. NISR urban areas, and population therein, were defined by administrative units, including true urban situations as well as peri-urban and even portion of rural areas (in the context of the forthcoming National Census NISR is reviewing the definition of urban and rural areas). This survey was focused on the "urbanized" areas only, excluding all rural components. This is why the results should not be directly applied to the urban population as defined by NISR statistics. In fact, in the Demand Module analysis, fuel saturation parameters resulting from this survey were weighted on the estimated fraction of NISR's urban households actually represented by the survey.

Table A1.1: Stratification of residential areas of Kigali and other urban areas according to housing density and determination of the distribution of the sample of households (HH) to be interviewed

			Housing system							
			High density		**Medium density**		**Sparse**			
			(Low income)		(Medium income)		(High income)		**Total**	
Province	**District**	**Cities**	HH (approx.)	Sample size (n. of HH)	HH (approx.)	Sample size (n. of HH)	HH (approx.)	Sample size (n. of HH)	HH (approx.)	Sample size (n. of HH)
City of Kigali	Nyarugenge	Kigali	1,169	38	1,549	32		0	2,718	70
	Kicukiro		1,668	53	4,851	101		0	6,519	155
	Gasabo		2,183	70	3,222	67	3,946	70	9,351	207
Total Kigali			5,020	**161**	9,622	**201**	3,946	**70**	18,588	**432**
Kigali approximate sampling intensity (% of HH)				3.2		2.1		1.8		2.3
Northern	Musanze	Ruhengeri	3,192	58	2,170	12	2,379	3	7,741	73
Southern	Huye	Butare	3,689	38	1,302	27	1,843	4	6,834	69
Eastern	Rwamagana	Rwamagana	3,283	33	2,250	9			5,533	42
Western	Rubavu	Gisenyi	2,004	68	2,911	33	1,464	5	6,379	106
Total other cities			12,168	**196**	8,633	**81**	5,686	**12**	26,487	**289**
Other cities - Approximate sampling intensity (% of HH)				1.6		0.9		0.2		1.1

Summary of survey results

The stratification based on characteristics of the residential areas, done with the scope of capturing the different income groups and respecting their proportions, has been quite efficient, as evidenced by the results shown in Table A1.2. As expected, the three strata based on housing densities show well distinct income levels and fuel consumption patterns. Saturation of cooking fuels by fuel type in Kigali and in other cities is shown in Table A.13. The penetrations of improved cooking stoves in Kigali and in Other urban areas are shown in Table A1.4 and A1.5, respectively. It should be once more emphasized that these values are not representative of the "NISR" urban sectors, which include peri-urban and even rural contexts, but refer to urbanized areas only.

Table A1.6 reports the per household fuel consumption in Kigali by fuel users categories, including the single-fuel users (colored cells) as well as mix-fuel users. Two situations were considered: the normal cooking day and the day when beans and other fuel-demanding meals are prepared. In the WISDOM Demand Module analysis we assumed that the fuel-demanding meals are prepared twice a week and the average daily consumption was calculated accordingly. Similarly, Table A1.7 reports the per household fuel consumption in other selected urban centers.

Table A1.2: Monthly income categories and fuel consumption by Housing systems in Kigali

	Sparse housing		Medium housing		Dense housing		General Mean	
Estimated monthly income (RWF)	***N***	**%**	***N***	**%**	***N***	**%**	***N***	**%**
0-100,000	*3*	5	*40*	**23.3**	*92*	**63**	*135*	**35.7**
100,001-200,000	*0*	0	*39*	**22.7**	*28*	**19.2**	*67*	**17.7**
200,001- 400,000	*6*	10	*39*	**22.7**	*8*	5.5	*53*	**14**
400,001-600,000	*7*	11.7	*24*	14	*1*	0.7	*32*	**8.5**
600,001-3,000,000	*32*	**53.3**	*13*	7.6	*1*	0.7	*46*	**12.2**
Over 3,000,000	*12*	**20**	*17*	9.9	*16*	11	*45*	**11.9**
	60	100	*172*	100	*146*	100	*378*	100

Quantity of fuel used per capita and per day for normal cooking	***N***	**Mean**	**Conf. Inter. @95% (±)**	***N***	**Mean**	**Conf. Inter. @95% (±)**	***N***	**Mean**	**Conf. Inter. @ 95% (±)**	***N***	**Mean**	**Conf. Inter. @95% (±)**
Firewood (kg)				*8*	**0.71**	*0.27*	*10*	**0.72**	*0.29*	*19*	**0.72**	**0.18**
Charcoal (kg)	*48*	**0.7**	*0.12*	*187*	**0.48**	*0.03*	*162*	**0.34**	*0.03*	*397*	**0.45**	**0.03**
LPG (kg)	*43*	**0.12**	*0.02*	*5*	0.17	*0.07*				*50*	**0.11**	**0.03**

Quantity of fuel used per capita and per day for "fuel-demanding" cooking												
Firewood (kg)				*10*	**0.91**	*0.25*	*13*	**1.09**	*0.32*	*23*	**1.2**	**0.19**
Charcoal (kg)	*49*	**0.9**	*0.12*	*182*	**0.8**	*0.05*	*157*	**0.6**	*0.04*	*388*	**0.75**	**0.01**
LPG (kg)	*40*	**0.15**	*0.03*							*40*	**0.12**	**0.02**

Note: "N" refers to the number of valid observations (to be noted that not all households provided valid answers to all questions).

Table A1.3: Saturation by fuel type including single-fuel users (80%) and proportional fractions of mixed fuel users (20%)

	Kigali city	**Huye**	**Musanze**	**Rubavu**	**Rwamagana**	**All other cities combined**
Number of valid observations (N)	*439*	*71*	*74*	*105*	*42*	*292*
Fuel types	%	%	%	%	%	%
Fuelwood	5.6	31.9	26.4	19.0	22.6	24.5
Charcoal	82.7	64.6	71.6	81.0	75.0	73.7
Total woodfuels	**88.3**	**96.5**	**98.0**	**100.0**	**97.6**	**98.3**
LPG	7.3	2.1	1.4	0.0	0.0	0.9
Electricity	4.2	0.0	0.7	0.0	1.2	0.3
Kerosene	0.2	1.4	0.0	0.0	1.2	0.5
Total Other fuels	**11.7**	**3.5**	**2.0**	**0.0**	**2.4**	**1.7**
	100	100	100	100	100	100.0

Table A1.4: Cooking stoves used by urban households of Kigali

Types of cooking fuel used by the household	Fuelwood Stoves improved fuelwood stoves	traditional fuelwood stoves	both improved & traditional	Total
Fuel wood		5		5
Fuel wood & charcoal	3	9		12
Fuel wood & saw dust	1			1
Total	**4**	**14**		**18**
Percent	***22.2***	***77.8***		

Types of cooking fuel used by the household	Charcoal Stoves improved charcoal stoves	traditional charcoal stoves	both improved & traditional	Total
Charcoal	246	71	5	322
Charcoal & LPG	9	8		17
Charcoal &electricity	15	2		17
Charcoal, gas &electricity	9			9
Electricity &Fuel wood Charcoal & LPG	1			1
Fuel wood & charcoal	18	6	1	25
Fuel wood, charcoal & electricity			1	1
Kerosene & Charcoal	1	1		2
Total	**299**	**88**	**7**	**413**
Percent	***72.4***	***21.3***	***1.7***	

Table A1.5: Cooking stoves used by urban households in Other urban areas

Types of cooking fuel used by the household	Fuelwood Stoves improved fuelwood stoves	traditional fuelwood stoves	both improved & traditional	Total
Fuel wood	9	26	1	36
Fuel wood & charcoal	9	19	12	40
Fuel wood & saw dust	1			1
Fuel wood & LPG	1			1
Total	**20**	**45**	**13**	**78**
Percent	***25.6***	***57.7***	***16.7***	***100.0***

Types of cooking fuel used by the household	Charcoal Stoves improved charcoal stoves	traditional charcoal stoves	both improved & traditional	Total
Charcoal	150	30		180
Charcoal &electricity	1			1
Fuel wood & charcoal	48	2		50
Fuel wood, charcoal & Saw dust	1			1
Total	**200**	**32**		**232**
Percent	***86.2***	***13.8***		***100.0***

Table A1.6: Daily household fuel consumption in Kigali by fuel users categories

Types of cooking fuel used by the household	Fuel used per household for a "normal" cooking day								
	Fuelwood			Charcoal			LPG		
	Mean (kg)	*N* [a]	Conf. Interval [b] (kg ±)	Mean (kg)	*N* [a]	Conf. Interval [b] (kg ±)	Mean (kg)	*N* [a]	Conf. Interval [b] (kg ±)
Fuel wood	**5.20**	*5*	3.8						
Charcoal				**2.63**	*325*	0.16	1	*1*	
LPG							**0.55**	*15*	0.14
Fuel wood & charcoal	4.1	*12*		2.36	*25*				
Fuel wood & saw dust	2.0	*1*							
Charcoal & LPG				3.1	*17*		0.7	*17*	
Charcoal &electricity				3.3	*17*				
LPG &Electricity							0.4	*5*	
Fuel wood, charcoal & electricity				5.0	*1*				
Kerosene &Charcoal				1.8	*2*				
Charcoal, gas &electricity				3.6	*9*		0.7	*10*	
Electricity, Fuelwood , Charcoal & LPG				6.0	*1*		1.5		
Total	**4.29**	*18*		**2.69**	*397*		**0.64**	*49*	

Types of cooking fuel used by the household	Fuel used per household for a "fuel-demanding" cooking day								
	Fuelwood			Charcoal			LPG		
	Mean (kg)	*N* [a]	Conf. Interval [b] (kg ±)	Mean (kg)	*N* [a]	Conf. Interval [b] (kg ±)	Mean (kg)	*N* [a]	Conf. Interval [b] (kg ±)
Fuel wood	**7.8**	*5*	3.1						
Charcoal				**4.4**	*318*	0.2	1.0	*1*	
LPG							**0.6**	*15*	0.1
Fuel wood & charcoal	5.8	*17*		3.8	*22*				
Fuel wood & saw dust	2.0	*1*							
Charcoal & LPG				4.1	*19*		0.8	*13*	
Charcoal &electricity				4.8	*16*				
LPG &Electricity							0.9	*4*	
Fuel wood, charcoal & electricity				7.0	*1*				
Kerosene &Charcoal				4.0	*2*				
Charcoal ,gas &electricity				4.8	*9*		0.9	*7*	
Electricity, Fuelwood, Charcoal & LPG				8.0	*1*		0.5	*1*	
Total	**6.0**	***23***		**4.4**	***388***		**0.7**	***41***	

Note: Colored cells identify the values associated to "pure users", which were used as reference for the analysis of WISDOM Demand Module.
[a] **N= Valid observations**
[b] **Confidence interval at 95% probability**

Table A1.7: Daily household fuel consumption in Other urban areas by fuel users categories

		Fuel used per household for a "normal" cooking day								
		Fuelwood			Charcoal			LPG		
	Types of cooking fuel used by the household	Mean (kg)	*N* [a]	Conf. Interval [b] (kg ±)	Mean (kg)	*N* [a]	Conf. Interval [b] (kg ±)	Mean (kg)	*N* [a]	Conf. Interval [b] (kg ±)
HUYE	Fuel wood	5.6	*6*	2.2						
	Charcoal				3.3	*31*	0.5			
	LPG							1.3	*1*	
	Fuel wood & charcoal	3.9	*16*	1.3	3.0	*27*	0.6			
	Fuel wood & saw dust	1.5	*1*							
	Fuel wood & LPG	6.0	*1*					1.3	*1*	
	Fuelwood, Charcoal & Saw dust				3.0	*1*				
	Total HUYE	**4.3**	***24***		**3.1**	***59***		**1.3**	***2***	
MUSANZE	Fuel wood	6.9	*13*	1.2						
	Charcoal				1.9	*46*	0.4			
	Fuel wood & charcoal	6.4	*11*	1.9	1.2	*13*	0.3			
	Charcoal &electricity				4.0	*1*				
	Total MUSANZE	**6.7**	***24***		**1.8**	***60***				
RUBAVU	Fuel wood	5.3	*12*	1.8						
	Charcoal				1.4	*77*	0.3			
	Fuel wood & charcoal	4.6	*13*	1.2	1.6	*16*	0.5			
	Total RUBAVU	**4.9**	***25***		**1.4**	***93***				
RWAMAGANA	Fuel wood	5.4	*6*	3.4						
	Charcoal				1.5	*28*	0.3			
	Fuel wood & charcoal	5.7	*7*	2.6	2.0	*6*	0.9			
	Total RWAMAGANA	**5.6**	***13***		**1.6**	***34***				

		Fuel used per household for a "fuel-demanding" cooking day								
		Fuel wood			Charcoal			LPG		
District	Types of cooking fuel used by the household	Mean (kg)	*N* [a]	Conf. Interval [b] (kg ±)	Mean (kg)	*N* [a]	Conf. Interval [b] (kg ±)	Mean (kg)	*N* [a]	Conf. Interval [b] (kg ±)
HUYE	Fuel wood	7.2	*6*	2.8						
	Charcoal	6.3	*2*		5.1	*28*	0.8	0	*3*	
	Fuel wood & charcoal	4.9	*28*	0.8	4.0	*17*	0.9	0		
	Total HUYE		***36***			***45***			***3***	
MUSANZE	Fuel wood	9.4	*13*	1.4	.					
	Charcoal				3.3	*46*	0.5			
	Fuel wood & charcoal	8.7	*13*	2.4	2.1	*13*	0.6			
	Total MUSANZE		*26*			*59*				
RUBAVU	Fuel wood	7.0	*12*	2.2	0.8					
	Charcoal				2.3	*76*	0.4			
	Fuel wood & charcoal	5.8	*16*	1.4	2.5	*15*	1.0			
	Total RUBAVU		*28*			*91*				
RWAMAGANA	Fuel wood	9.8	*5*	2.5						
	Charcoal				2.7	*28*	0.4			
	Fuel wood & charcoal	6.5	*7*	2.1	2.4	*7.0*	0.6			
	Total RWAMAGANA		*12*			*35*				

Note: Colored cells identify the values associated to "pure users", which were used as reference for the analysis of WISDOM Demand Module.

[a] **N= Valid observations**

[b] **Confidence interval at 95% probability**

ANNEX 2: CONSUMPTION PARAMETERS AND DISTRIC-WISE RESULTS

Table A2.1: 2009 household consumption

		Population 2009		Saturation in rural areas (%)			Saturation in urban area (%)			Construction wood (kg od per capita)		Total HH wood consumption t od/yr		
District (2006)	Code	**Rural**	**Urban**	Fuelwood	Charcoal	Other fuels	Fuelwood	Charcoal	Other fuels	Rural areas	Urban areas	Rural [a]	Urban	Total [a]
NYARUGENGE	101	24.603	251.936	63.0	36.5	0.5	16,1	76,3	7,6	7	4	16.115	266.801	282.916
GASABO	102	129.553	326.884	63.0	36.5	0.5	16,1	76,3	7,6	7	4	84.857	346.172	431.029
KICUKIRO	103	29.415	259.913	63.0	36.5	0.5	16,1	76,3	7,6	7	4	19.267	275.246	294.513
NYANZA	201	255.657	40.646	95.0	1.5	3.5	69,5	27,5	3,0	7	4	87.690	28.127	115.817
GISAGARA	202	318.151	9.545	95.0	1.5	3.5	69,5	27,5	3,0	7	4	109.126	6.605	115.731
NYARUGURU	203	294.906	0	95.0	1.5	3.5	69,5	27,5	3,0	7	4	101.153	0	101.153
HUYE	204	243.209	68.946	95.0	1.5	3.5	69,5	27,5	3,0	7	4	83.421	47.709	131.130
NYAMAGABE	205	293.547	29.509	95.0	1.5	3.5	69,5	27,5	3,0	7	4	100.687	20.420	121.107
RUHANGO	206	262.968	34.144	95.0	1.5	3.5	69,5	27,5	3,0	7	4	90.198	23.627	113.825
MUHANGA	207	216.754	78.632	95.0	1.5	3.5	69,5	27,5	3,0	7	4	74.347	54.414	128.761
KAMONYI	208	321.429	0	95.0	1.5	3.5	69,5	27,5	3,0	7	4	110.250	0	110.250
KARONGI	301	306.357	38.338	94.0	5.6	0.4	68,5	28,7	2,8	7	4	119.173	18.287	137.459
RUTSIRO	302	318.804	0	94.0	5.6	0.4	68,5	28,7	2,8	7	4	124.015	0	124.015
RUBAVU	303	312.854	93.264	94.0	5.6	0.4	68,5	28,7	2,8	7	4	121.700	44.487	166.187
NYABIHU	304	322.827	0	94.0	5.6	0.4	68,5	28,7	2,8	7	4	125.579	0	125.579
NGORORERO	305	333.878	0	94.0	5.6	0.4	68,5	28,7	2,8	7	4	129.879	0	129.879
RUSIZI	306	362.604	44.251	94.0	5.6	0.4	68,5	28,7	2,8	7	4	141.053	21.107	162.160
NYAMASHEKE	307	384.816	0	94.0	5.6	0.4	68,5	28,7	2,8	7	4	149.694	0	149.694
RULINDO	401	288.685	0	94.0	1.7	4.3	68,5	28,7	2,8	7	4	98.731	0	98.731
GAKENKE	402	342.300	0	94.0	1.7	4.3	68,5	28,7	2,8	7	4	117.067	0	117.067
MUSANZE	403	337.972	64.157	94.0	1.7	4.3	68,5	28,7	2,8	7	4	115.587	30.603	146.190
BURERA	404	349.605	0	94.0	1.7	4.3	68,5	28,7	2,8	7	4	119.565	0	119.565
GICUMBI	405	481.151	64.500	94.0	1.7	4.3	68,5	28,7	2,8	7	4	164.554	30.766	195.320
RWAMAGANA	501	286.147	19.974	94.0	2.2	3.8	68,5	28,7	2,8	7	4	99.579	9.527	109.106
NYAGATARE	502	369.422	33.555	94.0	2.2	3.8	68,5	28,7	2,8	7	4	128.559	16.005	144.565
GATSIBO	503	465.519	0	94.0	2.2	3.8	68,5	28,7	2,8	7	4	162.001	0	162.001
KAYONZA	504	316.799	0	94.0	2.2	3.8	68,5	28,7	2,8	7	4	110.247	0	110.247
KIREHE	505	316.420	0	94.0	2.2	3.8	68,5	28,7	2,8	7	4	110.114	0	110.114
NGOMA	506	297.269	15.335	94.0	2.2	3.8	68,5	28,7	2,8	7	4	103.449	7.315	110.764
BUGESERA	507	358.955	16.147	94.0	2.2	3.8	68,5	28,7	2,8	7	4	124.915	7.702	132.617
Total Rwanda		**8.942.576**	**1.489.675**									**3.242.570**	**1.254.922**	**4.497.492**

[a] The consumption here estimated includes conventional fuelwood as well as marginal woody biomass such as twigs, deadwood and annual pruning of farm trees and shrubs.

Table A2.2: 2020 households consumption - BAU scenario

		Population 2020		Saturation in rural areas (%)			Saturation in urban area (%)			Construction wood (kg od per capita)		total wood cons t od/yr		
District (2006)	Code	**Rural**	**Urban**	Fuelwood	Charcoal	Other fuels	Fuelwood	Charcoal	Other fuels	Rural areas	Urban areas	Rural [a]	Urban	Total [a]
NYARUGENGE	101	14.206	325.254	53.0	45.0	2.0	10	75	15	4	2	10.228	332.409	342.637
GASABO	102	139.891	532.741	53.0	45.0	2.0	10	75	15	4	2	100.721	544.460	645.181
KICUKIRO	103	26.342	391.770	53.0	45.0	2.0	10	75	15	4	2	18.966	400.389	419.355
NYANZA	201	323.138	85.514	92.3	2.2	5.5	66	30	4	4	2	109.544	61.741	171.285
GISAGARA	202	410.985	20.184	92.3	2.2	5.5	66	30	4	4	2	139.324	14.573	153.897
NYARUGURU	203	394.219	0	92.3	2.2	5.5	66	30	4	4	2	133.640	0	133.640
HUYE	204	247.539	138.469	92.3	2.2	5.5	66	30	4	4	2	83.916	99.976	183.892
NYAMAGABE	205	330.545	60.507	92.3	2.2	5.5	66	30	4	4	2	112.055	43.686	155.741
RUHANGO	206	307.305	70.605	92.3	2.2	5.5	66	30	4	4	2	104.176	50.977	155.153
MUHANGA	207	185.896	149.137	92.3	2.2	5.5	66	30	4	4	2	63.019	107.677	170.696
KAMONYI	208	415.512	0	92.3	2.2	5.5	66	30	4	4	2	140.858	0	140.858
KARONGI	301	394.713	53.994	90.3	8.7	1.0	66	30	4	4	2	161.833	25.755	187.588
RUTSIRO	302	403.929	0	90.3	8.7	1.0	66	30	4	4	2	165.611	0	165.611
RUBAVU	303	442.696	142.178	90.3	8.7	1.0	66	30	4	4	2	181.505	67.819	249.324
NYABIHU	304	408.165	0	90.3	8.7	1.0	66	30	4	4	2	167.348	0	167.348
NGORORERO	305	415.170	0	90.3	8.7	1.0	66	30	4	4	2	170.220	0	170.220
RUSIZI	306	463.184	61.885	90.3	8.7	1.0	66	30	4	4	2	189.906	29.519	219.425
NYAMASHEKE	307	478.751	0	90.3	8.7	1.0	66	30	4	4	2	196.288	0	196.288
RULINDO	401	347.482	0	90.3	2.6	7.1	66	30	4	4	2	117.101	0	117.101
GAKENKE	402	373.862	0	90.3	2.6	7.1	66	30	4	4	2	125.991	0	125.991
MUSANZE	403	448.497	102.957	90.3	2.6	7.1	66	30	4	4	2	151.144	49.110	200.254
BURERA	404	395.149	0	90.3	2.6	7.1	66	30	4	4	2	133.166	0	133.166
GICUMBI	405	725.978	112.791	90.3	2.6	7.1	66	30	4	4	2	244.655	53.801	298.456
RWAMAGANA	501	405.121	36.034	90.3	3.6	6.1	66	30	4	4	2	141.387	17.188	158.576
NYAGATARE	502	571.372	63.539	90.3	3.6	6.1	66	30	4	4	2	199.409	30.308	229.718
GATSIBO	503	751.806	0	90.3	3.6	6.1	66	30	4	4	2	262.380	0	262.380
KAYONZA	504	484.451	0	90.3	3.6	6.1	66	30	4	4	2	169.074	0	169.074
KIREHE	505	453.180	0	90.3	3.6	6.1	66	30	4	4	2	158.160	0	158.160
NGOMA	506	399.228	26.906	90.3	3.6	6.1	66	30	4	4	2	139.331	12.834	152.165
BUGESERA	507	516.881	29.401	90.3	3.6	6.1	66	30	4	4	2	180.392	14.025	194.416
Total Rwanda		**11.675.192**	**2.403.866**									**4.271.347**	**1.956.248**	**6.227.595**

[a] The consumption here estimated includes conventional fuelwood as well as marginal woody biomass such as twigs, deadwood and annual pruning of farm trees and shrubs.
Note: These totals and those presented in Table 2 differ slightly due to spatial smoothing applied in the mapping process.

Table A2.3: 2020 households consumption - AME scenario

District (2006)	Code	Population 2020		Saturation in rural areas (%)			Saturation in urban area (%)			Construction wood (kg od per capita)		total wood cons t od/yr		
		Rural	**Urban**	Fuelwood	Charcoal	Other fuels	Fuelwood	Charcoal	Other fuels	Rural areas	Urban areas	Rural [a]	Urban	Total [a]
NYARUGENGE	101	14.206	325.254	53.0	45.0	2.0	5	65	30	4	2	7.089	180.189	187.277
GASABO	102	139.891	532.741	53.0	45.0	2.0	5	65	30	4	2	69.805	295.135	364.940
KICUKIRO	103	26.342	391.770	53.0	45.0	2.0	5	65	30	4	2	13.144	217.041	230.185
NYANZA	201	323.138	85.514	92.3	2.2	5.5	60	30	10	4	2	98.880	40.363	139.243
GISAGARA	202	410.985	20.184	92.3	2.2	5.5	60	30	10	4	2	125.762	9.527	135.289
NYARUGURU	203	394.219	0	92.3	2.2	5.5	60	30	10	4	2	120.631	0	120.631
HUYE	204	247.539	138.469	92.3	2.2	5.5	60	30	10	4	2	75.747	65.358	141.105
NYAMAGABE	205	330.545	60.507	92.3	2.2	5.5	60	30	10	4	2	101.147	28.559	129.706
RUHANGO	206	307.305	70.605	92.3	2.2	5.5	60	30	10	4	2	94.035	33.326	127.361
MUHANGA	207	185.896	149.137	92.3	2.2	5.5	60	30	10	4	2	56.884	70.393	127.277
KAMONYI	208	415.512	0	92.3	2.2	5.5	60	30	10	4	2	127.147	0	127.147
KARONGI	301	394.713	53.994	90.3	8.7	1.0	60	30	10	4	2	136.966	18.142	155.108
RUTSIRO	302	403.929	0	90.3	8.7	1.0	60	30	10	4	2	140.164	0	140.164
RUBAVU	303	442.696	142.178	90.3	8.7	1.0	60	30	10	4	2	153.616	47.772	201.387
NYABIHU	304	408.165	0	90.3	8.7	1.0	60	30	10	4	2	141.633	0	141.633
NGORORERO	305	415.170	0	90.3	8.7	1.0	60	30	10	4	2	144.064	0	144.064
RUSIZI	306	463.184	61.885	90.3	8.7	1.0	60	30	10	4	2	160.725	20.793	181.518
NYAMASHEKE	307	478.751	0	90.3	8.7	1.0	60	30	10	4	2	166.127	0	166.127
RULINDO	401	347.482	0	90.3	2.6	7.1	60	30	10	4	2	104.940	0	104.940
GAKENKE	402	373.862	0	90.3	2.6	7.1	60	30	10	4	2	112.906	0	112.906
MUSANZE	403	448.497	102.957	90.3	2.6	7.1	60	30	10	4	2	135.446	34.594	170.040
BURERA	404	395.149	0	90.3	2.6	7.1	60	30	10	4	2	119.336	0	119.336
GICUMBI	405	725.978	112.791	90.3	2.6	7.1	60	30	10	4	2	219.246	37.898	257.143
RWAMAGANA	501	405.121	36.034	90.3	3.6	6.1	60	30	10	4	2	125.587	12.108	137.695
NYAGATARE	502	571.372	63.539	90.3	3.6	6.1	60	30	10	4	2	177.125	21.349	198.474
GATSIBO	503	751.806	0	90.3	3.6	6.1	60	30	10	4	2	233.060	0	233.060
KAYONZA	504	484.451	0	90.3	3.6	6.1	60	30	10	4	2	150.180	0	150.180
KIREHE	505	453.180	0	90.3	3.6	6.1	60	30	10	4	2	140.487	0	140.487
NGOMA	506	399.228	26.906	90.3	3.6	6.1	60	30	10	4	2	123.761	9.040	132.801
BUGESERA	507	516.881	29.401	90.3	3.6	6.1	60	30	10	4	2	160.234	9.880	170.113
Total Rwanda		**11.675.192**	**2.403.866**									**3.735.874**	**1.151.464**	**4.887.338**

[a] The consumption here estimated includes conventional fuelwood as well as marginal woody biomass such as twigs, deadwood and annual pruning of farm trees and shrubs.
Note: These totals and those presented in Table 2 differ slightly due to spatial smoothing applied in the mapping process.

Table A2.4: Summary of Household sector demand in 2009 and in 2020 according to BAU and ME scenarios. Values by District (oven dry t of wood)

			Households' woodfuel consumption [a]			Households' construction wood consumption			Total household wood consumption [a]		
District (2006)	Code	AREA_ha	2009	2020 - BAU	2020 - AME	2009	2020-BAU	2020-AME	2009	2020 - BAU	. 2020 -AME
NYARUGENGE	101	13,398	281,736	341,929	186,570	1,181	708	708	282,916	342,637	187,277
GASABO	102	42,922	428,814	643,558	363,317	2,215	1,623	1,623	431,029	645,181	364,940
KICUKIRO	103	16,673	293,268	418,468	229,298	1,245	887	887	294,513	419,355	230,185
NYANZA	201	67,216	113,865	169,821	137,779	1,952	1,464	1,464	115,817	171,285	139,243
GISAGARA	202	67,922	113,466	152,213	133,605	2,265	1,684	1,684	115,731	153,897	135,289
NYARUGURU	203	101,019	99,089	132,063	119,054	2,065	1,577	1,577	101,153	133,640	120,631
HUYE	204	58,158	129,152	182,624	139,837	1,978	1,268	1,268	131,130	183,892	141,105
NYAMAGABE	205	109,040	118,934	154,298	128,263	2,173	1,443	1,443	121,107	155,741	129,706
RUHANGO	206	62,683	111,848	153,783	125,991	1,977	1,370	1,370	113,825	155,153	127,361
MUHANGA	207	64,766	126,929	169,654	126,236	1,832	1,042	1,042	128,761	170,696	127,277
KAMONYI	208	65,551	108,000	139,196	125,485	2,250	1,662	1,662	110,250	140,858	127,147
KARONGI	301	99,309	135,162	185,902	153,421	2,298	1,687	1,687	137,459	187,588	155,108
RUTSIRO	302	115,695	121,783	163,995	138,548	2,232	1,616	1,616	124,015	165,611	140,164
RUBAVU	303	38,839	163,623	247,270	199,333	2,564	2,054	2,054	166,187	249,324	201,387
NYABIHU	304	53,133	123,320	165,715	140,000	2,259	1,633	1,633	125,579	167,348	141,633
NGORORERO	305	67,895	127,542	168,559	142,403	2,337	1,661	1,661	129,879	170,220	144,064
RUSIZI	306	95,813	159,445	217,449	179,541	2,715	1,977	1,977	162,160	219,425	181,518
NYAMASHEKE	307	117,358	147,000	194,373	164,212	2,694	1,915	1,915	149,694	196,288	166,127
RULINDO	401	56,696	96,710	115,711	103,550	2,021	1,390	1,390	98,731	117,101	104,940
GAKENKE	402	70,408	114,671	124,496	111,411	2,396	1,495	1,495	117,067	125,991	112,906
MUSANZE	403	53,025	143,567	198,254	168,040	2,623	2,000	2,000	146,190	200,254	170,040
BURERA	404	64,445	117,118	131,585	117,755	2,447	1,581	1,581	119,565	133,166	119,336
GICUMBI	405	82,955	191,694	295,327	254,014	3,626	3,129	3,129	195,320	298,456	257,143
RWAMAGANA	501	68,201	107,024	156,883	136,003	2,083	1,692	1,692	109,106	158,576	137,695
NYAGATARE	502	191,941	141,844	227,305	196,062	2,721	2,413	2,413	144,565	229,718	198,474
GATSIBO	503	158,218	158,742	259,373	230,053	3,259	3,007	3,007	162,001	262,380	233,060
KAYONZA	504	193,474	108,029	167,136	148,242	2,218	1,938	1,938	110,247	169,074	150,180
KIREHE	505	118,371	107,899	156,347	138,674	2,215	1,813	1,813	110,114	158,160	140,487
NGOMA	506	86,772	108,622	150,514	131,151	2,143	1,650	1,650	110,764	152,165	132,801
BUGESERA	507	129,038	130,041	192,290	167,987	2,576	2,127	2,127	132,617	194,416	170,113
	Total	**2,530,933**	**4,428,936**	**6,176,089**	**4,835,832**	**68,557**	**51,506**	**51,506**	**4,497,492**	**6,227,595**	**4,887,338**

[a] The consumption here estimated includes conventional fuelwood as well as marginal woody biomass such as twigs, deadwood and annual pruning of farm trees and shrubs.

Table A2.5: Summary of woodfuel demand by Commercial, Public and Industrial sectors in 2009 and 2020 according to BAU and ME scenarios. Values by District (oven dry t of wood)

		Commercial			Secondary. schools			Prisons			Tea factories			Brick making			Total Other sectors		
District (2006)	Code	2009	2020 - BAU	2020 - AME	2009	2020- BAU	2020- AME	2009	2020- BAU	2020- AME	2009	2020- BAU	2020- AME	2009	2020- BAU	2020- AME	2009	2020 - BAU	2020 - AME
NYARUGENGE	101	26,575	33,171	17,950	1,839	3,257	1,629	3,643	2,732	1,366	0	0	0	2,386	2,386	2,386	**34,443**	41,547	23,331
GASABO	102	34,473	54,327	29,400	2,920	5,173	2,587	4,833	3,624	1,812	0	0	0	1,362	1,362	1,362	**43,588**	64,487	35,161
KICUKIRO	103	27,413	39,953	21,620	2,055	3,641	1,820	0	0	0	0	0	0	1,137	1,137	1,137	**30,605**	44,730	24,577
NYANZA	201	2,796	6,157	4,019	885	1,729	865	1,976	1,482	741	0	0	0	894	894	894	**6,551**	10,262	6,519
GISAGARA	202	657	1,453	948	590	1,153	576	0	0	0	0	0	0	652	652	652	**1,899**	3,258	2,177
NYARUGURU	203	0	0	0	531	1,038	519	0	0	0	4,052	4,052	4,052	1,685	1,685	1,685	**6,268**	6,775	6,256
HUYE	204	4,743	9,968	6,507	1,121	2,191	1,095	4,229	3,172	1,586	0	0	0	5,454	5,454	5,454	**15,547**	20,785	14,643
NYAMAGABE	205	2,030	4,356	2,844	1,003	1,960	980	1,839	1,380	690	2,181	2,181	2,181	886	886	886	**7,939**	10,763	7,580
RUHANGO	206	2,349	5,083	3,318	1,238	2,421	1,211	0	0	0	0	0	0	5,270	5,270	5,270	**8,857**	12,774	9,799
MUHANGA	207	5,409	10,737	7,009	1,121	2,191	1,095	3,300	2,475	1,237	0	0	0	2,254	2,254	2,254	**12,083**	17,656	11,596
KAMONYI	208	0	0	0	708	1,384	692	0	0	0	0	0	0	894	894	894	**1,602**	2,278	1,586
KARONGI	301	1,813	2,565	1,803	1,434	3,031	1,516	0	0	0	1,823	1,823	1,823	1,810	1,810	1,810	**6,881**	9,229	6,951
RUTSIRO	302	0	0	0	717	1,516	758	0	0	0	0	0	0	671	671	671	**1,388**	2,187	1,429
RUBAVU	303	4,411	6,753	4,748	1,239	2,618	1,309	1,229	922	461	1,589	1,589	1,589	4,069	4,069	4,069	**12,537**	15,951	12,176
NYABIHU	304	0	0	0	913	1,929	964	0	0	0	997	997	997	681	681	681	**2,591**	3,607	2,643
NGORORERO	305	0	0	0	913	1,929	964	0	0	0	1,500	1,500	1,500	1,338	1,338	1,338	**3,750**	4,766	3,802
RUSIZI	306	2,092	2,939	2,066	1,043	2,204	1,102	1,667	1,250	625	2,659	2,659	2,659	1,112	1,112	1,112	**8,572**	10,164	7,563
NYAMASHEKE	307	0	0	0	978	2,067	1,033	0	0	0	5,096	5,096	5,096	11,724	11,724	11,724	**17,799**	18,887	17,854
RULINDO	401	0	0	0	1,255	2,913	1,457	0	0	0	4,049	4,049	4,049	1,361	1,361	1,361	**6,666**	8,324	6,867
GAKENKE	402	0	0	0	1,088	2,525	1,262	0	0	0	0	0	0	17,393	17,393	17,393	**18,481**	19,918	18,656
MUSANZE	403	3,033	4,889	3,437	1,422	3,302	1,651	822	616	308	0	0	0	8,597	8,597	8,597	**13,874**	17,404	13,993
BURERA	404	0	0	0	1,088	2,525	1,262	0	0	0	0	0	0	668	668	668	**1,756**	3,193	1,931
GICUMBI	405	3,050	5,357	3,767	1,506	3,496	1,748	943	708	354	5,063	5,063	5,063	4,741	4,741	4,741	**15,303**	19,364	15,672
RWAMAGANA	501	945	1,712	1,203	1,015	2,430	1,215	3,675	2,756	1,378	0	0	0	1,273	1,273	1,273	**6,907**	8,171	5,069
NYAGATARE	502	1,587	3,018	2,122	1,268	3,038	1,519	999	749	375	0	0	0	874	874	874	**4,728**	7,679	4,889
GATSIBO	503	0	0	0	1,268	3,038	1,519	0	0	0	0	0	0	652	652	652	**1,921**	3,690	2,171
KAYONZA	504	0	0	0	1,268	3,038	1,519	0	0	0	0	0	0	660	660	660	**1,928**	3,698	2,179
KIREHE	505	0	0	0	507	1,215	608	0	0	0	0	0	0	888	888	888	**1,395**	2,103	1,495
NGOMA	506	725	1,278	899	1,184	2,835	1,418	1,048	786	393	0	0	0	654	654	654	**3,611**	5,553	3,363
BUGESERA	507	763	1,396	980	761	1,823	911	1,981	1,486	743	0	0	0	890	890	890	**4,395**	5,594	3,524
	Total	**124,863**	**195,112**	**114,640**	**34,878**	**73,606**	**36,803**	**32,184**	**24,138**	**12,069**	**29,010**	**29,010**	**29,010**	**82,928**	**82,928**	**82,928**	**303,863**	**404,794**	**275,450**

Table A2.6: Summary of woody biomass demand by all sectors in 2009 and 2020 according to BAU and ME scenarios. Values by District (oven dry t of wood)

			Total HH sector demand [a]			Total Other sectors			Total demand [a]		
District (2006)	Code	AREA_ha	2009	2020 - BAU	2020 -AME	2009	2020 - BAU9	2020 - AME	2009	2020 - BAU9	2020 - AME
NYARUGENGE	101	13,398	282,916	342,637	187,277	**34,443**	41,547	23,331	**317,359**	384,184	210,608
GASABO	102	42,922	431,029	645,181	364,940	**43,588**	64,487	35,161	**474,617**	709,668	400,101
KICUKIRO	103	16,673	294,513	419,355	230,185	**30,605**	44,730	24,577	**325,118**	464,085	254,762
NYANZA	201	67,216	115,817	171,285	139,243	**6,551**	10,262	6,519	**122,368**	181,547	145,762
GISAGARA	202	67,922	115,731	153,897	135,289	**1,899**	3,258	2,177	**117,630**	157,155	137,466
NYARUGURU	203	101,019	101,153	133,640	120,631	**6,268**	6,775	6,256	**107,421**	140,415	126,887
HUYE	204	58,158	131,130	183,892	141,105	**15,547**	20,785	14,643	**146,677**	204,677	155,747
NYAMAGABE	205	109,040	121,107	155,741	129,706	**7,939**	10,763	7,580	**129,046**	166,504	137,286
RUHANGO	206	62,683	113,825	155,153	127,361	**8,857**	12,774	9,799	**122,683**	167,927	137,160
MUHANGA	207	64,766	128,761	170,696	127,277	**12,083**	17,656	11,596	**140,843**	188,352	138,873
KAMONYI	208	65,551	110,250	140,858	127,147	**1,602**	2,278	1,586	**111,852**	143,136	128,733
KARONGI	301	99,309	137,459	187,588	155,108	**6,881**	9,229	6,951	**144,340**	196,817	162,059
RUTSIRO	302	115,695	124,015	165,611	140,164	**1,388**	2,187	1,429	**125,403**	167,798	141,593
RUBAVU	303	38,839	166,187	249,324	201,387	**12,537**	15,951	12,176	**178,724**	265,275	213,563
NYABIHU	304	53,133	125,579	167,348	141,633	**2,591**	3,607	2,643	**128,170**	170,954	144,275
NGORORERO	305	67,895	129,879	170,220	144,064	**3,750**	4,766	3,802	**133,629**	174,986	147,865
RUSIZI	306	95,813	162,160	219,425	181,518	**8,572**	10,164	7,563	**170,733**	229,589	189,081
NYAMASHEKE	307	117,358	149,694	196,288	166,127	**17,799**	18,887	17,854	**167,492**	215,175	183,981
RULINDO	401	56,696	98,731	117,101	104,940	**6,666**	8,324	6,867	**105,396**	125,425	111,807
GAKENKE	402	70,408	117,067	125,991	112,906	**18,481**	19,918	18,656	**135,548**	145,909	131,562
MUSANZE	403	53,025	146,190	200,254	170,040	**13,874**	17,404	13,993	**160,064**	217,658	184,033
BURERA	404	64,445	119,565	133,166	119,336	**1,756**	3,193	1,931	**121,321**	136,359	121,266
GICUMBI	405	82,955	195,320	298,456	257,143	**15,303**	19,364	15,672	**210,623**	317,820	272,815
RWAMAGANA	501	68,201	109,106	158,576	137,695	**6,907**	8,171	5,069	**116,013**	166,746	142,764
NYAGATARE	502	191,941	144,565	229,718	198,474	**4,728**	7,679	4,889	**149,293**	237,396	203,364
GATSIBO	503	158,218	162,001	262,380	233,060	**1,921**	3,690	2,171	**163,921**	266,071	235,232
KAYONZA	504	193,474	110,247	169,074	150,180	**1,928**	3,698	2,179	**112,175**	172,772	152,359
KIREHE	505	118,371	110,114	158,160	140,487	**1,395**	2,103	1,495	**111,509**	160,263	141,983
NGOMA	506	86,772	110,764	152,165	132,801	**3,611**	5,553	3,363	**114,375**	157,717	136,164
BUGESERA	507	129,038	132,617	194,416	170,113	**4,395**	5,594	3,524	**137,012**	200,010	173,637
	Total	**2,530,933**	**4,497,492**	**6,227,595**	**4,887,338**	**303,863**	**404,794**	**275,450**	**4,801,356**	**6,632,389**	**5,162,788**

[a] The consumption here estimated includes conventional fuelwood as well as marginal woody biomass such as twigs, deadwood and annual pruning of farm trees and shrubs.

Table A2.7: District-wise charcoal consumption in 2009 and projected consumption in 2020 according to BAU and AME scenarios. Summary of household and commercial consumption. Values by District (t of charcoal)

Values= tons of charcoal	Charcoal consumption 2009			Charcoal consumption 2020 - BAU			Charcoal consumption 2020 - AME		
District (2006)	**Rural**	**Urban**	**Total**	**Rural**	**Urban**	**Total**	**Rural**	**Urban**	**Total**
NYARUGENGE	1,575	40,914	**42,489**	1,121	51,943	**53,064**	1,034	42,325	**43,358**
GASABO	8,294	53,083	**61,377**	11,042	85,076	**96,118**	10,180	69,324	**79,503**
KICUKIRO	1,883	42,211	**44,094**	2,079	62,566	**64,645**	1,917	50,982	**52,899**
NYANZA	673	3,098	**3,770**	1,247	7,114	**8,361**	1,150	6,180	**7,330**
GISAGARA	837	727	**1,564**	1,587	1,679	**3,266**	1,463	1,459	**2,922**
NYARUGURU	776	0	**776**	1,522	0	**1,522**	1,403	0	**1,403**
HUYE	640	5,255	**5,895**	956	11,520	**12,475**	881	10,008	**10,889**
NYAMAGABE	772	2,249	**3,021**	1,276	5,034	**6,310**	1,177	4,373	**5,550**
RUHANGO	692	2,602	**3,294**	1,186	5,874	**7,060**	1,094	5,103	**6,197**
MUHANGA	570	5,993	**6,562**	718	12,407	**13,125**	662	10,778	**11,439**
KAMONYI	845	0	**845**	1,604	0	**1,604**	1,479	0	**1,479**
KARONGI	3,008	1,459	**4,467**	6,023	2,148	**8,171**	5,554	1,871	**7,425**
RUTSIRO	3,131	0	**3,131**	6,164	0	**6,164**	5,684	0	**5,684**
RUBAVU	3,072	3,549	**6,621**	6,756	5,656	**12,411**	6,229	4,927	**11,156**
NYABIHU	3,170	0	**3,170**	6,229	0	**6,229**	5,743	0	**5,743**
NGORORERO	3,278	0	**3,278**	6,336	0	**6,336**	5,842	0	**5,842**
RUSIZI	3,561	1,685	**5,245**	7,068	2,461	**9,530**	6,517	2,145	**8,662**
NYAMASHEKE	3,779	0	**3,779**	7,306	0	**7,306**	6,736	0	**6,736**
RULINDO	860	0	**860**	1,585	0	**1,585**	1,459	0	**1,459**
GAKENKE	1,020	0	**1,020**	1,705	0	**1,705**	1,570	0	**1,570**
MUSANZE	1,007	2,441	**3,449**	2,045	4,096	**6,141**	1,884	3,568	**5,452**
BURERA	1,042	0	**1,042**	1,802	0	**1,802**	1,660	0	**1,660**
GICUMBI	1,434	2,455	**3,889**	3,311	4,487	**7,797**	3,049	3,908	**6,957**
RWAMAGANA	1,105	760	**1,865**	2,556	1,433	**3,990**	2,358	1,249	**3,606**
NYAGATARE	1,426	1,277	**2,703**	3,605	2,527	**6,133**	3,326	2,202	**5,528**
GATSIBO	1,797	0	**1,797**	4,744	0	**4,744**	4,373	0	**4,373**
KAYONZA	1,223	0	**1,223**	3,057	0	**3,057**	2,821	0	**2,821**
KIREHE	1,222	0	**1,222**	2,859	0	**2,859**	2,637	0	**2,637**
NGOMA	1,147	584	**1,731**	2,519	1,070	**3,589**	2,324	932	**3,256**
BUGESERA	1,385	614	**2,000**	3,261	1,171	**4,432**	3,008	1,020	**4,028**
Total Rwanda	**55,222**	**170,955**	**226,177**	**103,268**	**268,261**	**371,529**	**95,214**	**222,351**	**317,565**

ANNEX 3: FOREST COVER MAP FEATURES AND PRODUCTIVITY PARAMETERS

Procedure for the standardization of Forest Cover Map features

1. Reception of District-wise forest map and creation of new fields in each District map with standard name and format (Category, Species, Code, Density), transfer of attributes from original heterogeneous fields and deletion of original fields.
2. Re-projection to mach the WISDOM dataset and integration of district maps into a geodatabase (forest29sep2012.mdb) and into a single map (for29sep).
3. Standardization of map attributes through look-up tables and definition of unique coding defining formation, species and density, as shown in Table 19.
4. Conversion from vector to raster based on *uni_f_spp_den* and inclusion of province code.
5. Allocation of stock and MAI values to individual map features based on available references:
   a. Per ha values of productivity for eucalyptus, pinus and few other species by province are derived from ISAR results, which refer to average density conditions (province means). The species adequately covered by ISAR inventory represent some 95-97% of the plantation area (highlighted in Table A3.1, Annex 3).
   b. Estimation of average plantation density by species and by province in order to determine the average density-stock-MAI relation for each species in each province.
   c. Allocation of stock and productivity parameters to each plantation pixel (by species and province) weighted on the specific density parameter (average species stock and MAI/ha in $province_i$) / (average species density in $province_i$) * (density of $pixel_j$ in $province_i$).

Table A3.1: Map attributes associated to each polygon

code	Form_rev
1	Plantation
2	Bamboo
3	Closed Natural Forest
4	Degraded Natural Forest
5	Natural_shrubs
6	Wooded_savannah
9	Undefined

dens	class	Remarks
0	undefined	
1	10-40%	Used for plantations, shrubs and w. savannah
2	40-70%	
3	>70%	
4	<50%	(DNF only)
5	>=50%	(CNF only)

code	province
1	Kigali
2	Southern
3	Western
4	Northern
5	Eastern

code	Species_rev (pure)	Code_rev
1	Acacia mearnsii (Black Wattle)	Ac_mea
2	Acacia melanoxylon	Ac_mel
3	Alnus	Al
4	Callitris	Ca
5	Cupressus	Cu
6	Eucalyptus spp	Eu
7	Grevillea	Gr
8	Jacaranda mimosifolia	Ja
9	Maesopsis	Mae
10	Pinus spp	Pi
11	Bamboo spp	Bam_spp
12	Acacia kikrii	Ac_kik
99	Others, Undefined	Undef

code	Species_rev (mixed)	Code_rev
499	Callitris & Other spp	Ca&Oth
599	Cupressus & Other spp	Cu&Oth
601	Eucalyptus & Acacias	Eu&Ac
604	Eucalyptus & Callitris	Eu&Ca
605	Eucalyptus & Cupressus	Eu&Cu
607	Eucalyptus & Grevillea	Eu&Gr
610	Eucalyptus & Pinus	Eu&Pi
611	Eucalyptus & Bamboo	Eu&Bam
699	Eucalyptus & Other spp	Eu&Oth
799	Grevillea & Other spp	Gr&Oth
1006	Pinus & Eucalyptus	Pi&Euc
1099	Pinus & Other spp	Pi&Oth
9899	Mixed spp (arboretum)	Arb
9999	Mixed spp (undefined)	Mix

Plantations' productivity parameters

Table A3.2: Plantation area by species and density classes, and selected MAI values according to Low and High productivity variants.

		Plantation area (ha)				**MAI - Low productivity variant** (m³ ha⁻¹ yr⁻¹)					**MAI - High productivity variant** (m³ ha⁻¹ yr⁻¹)				
		Crown cover classes						MAI by crown cover classes					MAI by crown cover classes		
Province	species	10-40%	40-70%	>70%	Total	Average	Reference/source	10-40%	40-70%	>70%	Average	Reference/source	10-40%	40-70%	>70%
Eastern	Acacia kikrii	23	5	9	36	7.7	Oth sp nat avg	4.4	9.7	14.9	9.2	= LOW VAR. +20%	5.3	11.6	17.9
	Acacia mearnsii (B. Wattle)	3	0	0	3	7.7	Oth sp nat avg	7.7			9.2	= LOW VAR. +20%	9.2		
	Acacia melanoxylon	0	1	13	14	15.0	Sp nat avg		10.0	15.5	18.0	= LOW VAR. +20%		12.0	18.6
	Callitris	3	68	62	133	6.9	Sp nat avg	2.5	5.5	8.5	8.3	= LOW VAR. +20%	3.0	6.6	10.2
	Cupressus	1	1	15	17	4.6	Sp nat avg	1.4	3.1	4.9	5.5	= LOW VAR. +20%	1.7	3.8	5.8
	Eucalyptus spp	4,094	15,097	13,492	32,682	**6.3**	**Sp prov avg**	2.5	5.5	8.4	**9.9**	**weighted SEW-IFDC**	3.9	8.5	13.2
	Grevillea	19	69	50	138	6.8	Sp nat avg	2.8	6.1	9.4	8.2	= LOW VAR. +20%	3.3	7.3	11.3
	Jacaranda mimosifolia	21	66	129	215	7.7	Oth sp nat avg	2.7	6.0	9.3	9.2	= LOW VAR. +20%	3.3	7.2	11.1
	Pinus spp	20	80	1,106	1,206	**8.6**	**Sp prov/nat avg**	2.6	5.8	8.9	10.4	= LOW VAR. +20%	3.2	6.9	10.7
	Undefined	15	131	128	274	7.7	Oth sp nat avg	2.8	6.3	9.7	9.2	= LOW VAR. +20%	3.4	7.5	11.6
	Mixed plantations	219	814	177	1,209	7.3	weighted on spp mix	4.0	7.7	9.5	9.1	weighted on spp values	5.0	9.5	12.1
Kigali	Acacia melanoxylon	0	1	1	2	15.0	Sp nat avg		12.7	19.6	18.0	= LOW VAR. +20%		15.2	23.5
	Callitris	0	0	8	8	6.9	Sp nat avg			6.9	8.3	= LOW VAR. +20%			8.3
	Cupressus	0	14	1	14	4.6	Sp nat avg		4.5	6.9	5.5	= LOW VAR. +20%		5.4	8.3
	Eucalyptus spp	1,736	3,586	3,708	9,030	**6.3**	**Sp prov avg**	2.6	5.6	8.7	11.9	Mean North and East Prov	4.8	10.6	16.5
	Grevillea	0	4	9	12	6.8	Sp nat avg		4.9	7.6	8.2	= LOW VAR. +20%		5.9	9.2
	Pinus spp	3	1	94	98	**13.0**	**Sp prov/nat avg**	3.9	8.6	13.3	15.6	= LOW VAR. +20%	4.7	10.3	16.0
	Undefined	24	6	16	45	7.7	Oth sp nat avg	3.9	8.5	13.1	9.2	= LOW VAR. +20%	4.6	10.2	15.7
	Mixed plantations	28	297	736	1,061	8.3	weighted on spp mix	3.1	6.6	9.3	12.5	weighted on spp values	4.5	9.6	13.9
Northern	Acacia mearnsii (B. Wattle)	0	0	0	0	7.7	Oth sp nat avg		7.7		9.2	= LOW VAR. +20%		9.2	
	Alnus	1	3	0	3	7.7	Oth sp nat avg	3.8	8.4		9.2	= LOW VAR. +20%	4.6	10.1	
	Callitris	3	37	25	65	6.9	Sp nat avg	2.6	5.8	9.0	8.3	= LOW VAR. +20%	3.2	7.0	10.8
	Cupressus	1	10	9	20	4.6	Sp nat avg	1.7	3.7	5.7	5.5	= LOW VAR. +20%	2.0	4.5	6.9
	Eucalyptus spp	4,315	26,099	23,645	54,059	**7.2**	**Sp prov avg**	2.7	6.0	9.3	**14.0**	**weighted SEW-IFDC**	5.3	11.7	18.1
	Grevillea	1	11	1	13	6.8	Sp nat avg	3.2	7.0	10.7	8.2	= LOW VAR. +20%	3.8	8.3	12.9
	Pinus spp	3	30	179	211	**13.0**	**Sp prov/nat avg**	4.1	8.9	13.8	15.6	= LOW VAR. +20%	4.9	10.7	16.5
	Undefined	0	8	17	25	7.7	Oth sp nat avg	2.6	5.6	8.7	9.2	= LOW VAR. +20%	3.1	6.8	10.5
	Mixed plantations	35	192	82	310	7.7	weighted on spp mix	3.3	7.3	10.4	10.2	weighted on spp values	4.3	9.3	14.8

cont/ed Table A.3.2

		Plantation area (ha)				MAI - Low productivity variant ($m^3\ ha^{-1}\ yr^{-1}$)					MAI - High productivity variant ($m^3\ ha^{-1}\ yr^{-1}$)				
		Crown cover classes						MAI by crown cover classes					MAI by crown cover classes		
Province	species	10-40%	40-70%	>70%	Total	Average	Reference/source	10-40%	40-70%	>70%	Average	Reference/source	10-40%	40-70%	>70%
Southern	Acacia mearnsii (B. Wattle)	0	0	1	1	7.7	Oth sp nat avg			7.7	9.2	= LOW VAR. +20%			9.2
	Acacia melanoxylon	0	128	793	921	15.0	Sp nat avg		10.2	15.8	18.0	= LOW VAR. +20%		12.2	18.9
	Bamboo spp	0	0	1	1	0.0	No woodfuel prod.			0.0	0.0	= LOW VAR. +20%			0.0
	Callitris	42	142	410	593	6.9	Sp nat avg	2.3	5.1	7.9	8.3	= LOW VAR. +20%	2.8	6.2	9.5
	Cupressus	2	13	43	57	4.6	Sp nat avg	1.5	3.3	5.1	5.5	= LOW VAR. +20%	1.8	3.9	6.1
	Eucalyptus spp	12,494	46,427	36,849	95,769	**10.2**	**Sp prov avg**	4.1	9.0	13.8	**21.4**	**weighted SEW-IFDC**	8.6	18.8	29.1
	Grevillea	3	26	35	64	6.8	Sp nat avg	2.4	5.4	8.3	8.2	= LOW VAR. +20%	2.9	6.4	9.9
	Jacaranda mimosifolia	0	0	2	2	7.7	Oth sp nat avg			7.7	9.2	= LOW VAR. +20%			9.2
	Maesopsis	0	0	2	2	7.7	Oth sp nat avg			7.7	9.2	= LOW VAR. +20%			9.2
	Pinus spp	257	1,212	6,405	7,874	**12.7**	**Sp prov/nat avg**	4.0	8.9	13.7	15.2	= LOW VAR. +20%	4.8	10.7	16.5
	Undefined	166	483	35	684	7.7	Oth sp nat avg	3.9	8.6	13.2	9.2	= LOW VAR. +20%	4.7	10.3	15.9
	Mixed plantations	339	2,296	1,384	4,019	10.0	weighted on spp mix	5.4	10.2	10.8	15.9	weighted on spp values	8.8	17.1	15.6
Western	Acacia mearnsii (B. Wattle)	0	0	1	1	7.7	Oth sp nat avg			7.7	9.2	= LOW VAR. +20%			9.2
	Acacia melanoxylon	1	271	358	630	15.0	Sp nat avg	5.2	11.5	17.7	18.0	= LOW VAR. +20%	6.2	13.7	21.2
	Alnus	15	24	27	65	7.7	Oth sp nat avg	3.2	7.0	10.8	9.2	= LOW VAR. +20%	3.8	8.4	12.9
	Bamboo spp	0	5	13	18	0.0	No woodfuel prod.		0.0	0.0	0.0	= LOW VAR. +20%		0.0	0.0
	Callitris	2	105	47	154	6.9	Sp nat avg	2.7	5.9	9.2	8.3	= LOW VAR. +20%	3.2	7.1	11.0
	Cupressus	0	8	83	91	4.6	Sp nat avg		3.0	4.7	5.5	= LOW VAR. +20%		3.6	5.6
	Eucalyptus spp	6,989	37,360	18,526	62,874	**12.3**	**Sp prov avg**	5.1	11.2	17.3	**21.4**	**SEW-IFDC (South Prov.)**	8.9	19.5	30.1
	Grevillea	83	68	15	166	6.8	Sp nat avg	4.0	8.8	13.5	8.2	= LOW VAR. +20%	4.8	10.5	16.2
	Maesopsis	0	0	2	2	7.7	Oth sp nat avg			7.7	9.2	= LOW VAR. +20%			9.2
	Pinus spp	137	1,350	7,943	9,431	**14.2**	**Sp prov/nat avg**	4.4	9.8	15.1	17.0	= LOW VAR. +20%	5.3	11.7	18.1
	Undefined	74	126	58	258	7.7	Oth sp nat avg	3.6	7.9	12.3	9.2	= LOW VAR. +20%	4.3	9.5	14.7
	Mixed plantations	88	1,236	882	2,206	10.7	weighted on spp mix	4.5	9.5	12.9	15.4	weighted on spp values	6.6	13.8	18.6
		31,256	137,907	117,634	286,797										

Note: **Bolded values** are based on provincial-level survey data; Normal values indicate national-level survey data; grey values indicate values inferred (based on density) or tentatively estimated)

Table A3.3: Supply Module - District-level summary of woody biomass productivity in 2009 and in 2020 (BAU scenario) according to productivity variants. Values are thousand oven-dry t of woody biomass.

(kt od/year)	2009-Mean annual increment (MAI)			Accessible MAI - 2009			Available MAI [a] - 2009			Available MAI [a] - 2020		
	Productivity variant			Productivity variant			Productivity variant			Productivity variant		
District	Low	**Medium**	High	Low	**Medium**	High	Low	**Medium**	High	Low	**Medium**	High
NYARUGENGE	13.96	**18.7**	23.4	14.0	**18.7**	23.4	13.6	**18.3**	23.1	14.7	**19.8**	25.0
GASABO	40.3	**56.5**	72.8	40.3	**56.5**	72.8	39.3	**55.5**	71.8	42.3	**60.0**	77.6
KICUKIRO	8.7	**11.7**	14.7	8.7	**11.7**	14.7	8.6	**11.6**	14.6	9.1	**12.3**	15.5
NYANZA	62.9	**91.9**	121.0	62.9	**91.9**	121.0	61.4	**90.4**	119.4	65.8	**97.2**	128.6
GISAGARA	81.3	**117.9**	154.5	81.3	**117.9**	154.5	79.2	**115.7**	152.3	85.6	**125.3**	165.1
NYARUGURU	294.8	**434.2**	573.6	257.6	**392.1**	526.6	249.9	**384.1**	518.3	272.9	**419.6**	566.5
HUYE	97.7	**147.7**	197.8	97.7	**147.7**	197.8	94.9	**144.9**	194.8	103.1	**157.5**	212.0
NYAMAGABE	241.0	**339.5**	438.0	204.4	**298.9**	393.4	198.6	**293.0**	387.4	215.9	**318.7**	421.7
RUHANGO	50.7	**74.8**	99.0	50.7	**74.8**	99.0	49.5	**73.6**	97.7	52.9	**78.8**	104.8
MUHANGA	103.6	**152.0**	200.4	103.6	**152.0**	200.4	100.8	**149.1**	197.5	109.1	**161.6**	214.1
KAMONYI	70.8	**105.3**	139.8	70.8	**105.3**	139.8	69.0	**103.4**	137.8	74.3	**111.7**	149.1
KARONGI	175.2	**237.0**	298.7	173.6	**235.2**	296.8	168.8	**230.6**	292.4	183.4	**250.4**	317.6
RUTSIRO	125.0	**167.2**	209.4	101.0	**136.5**	171.9	98.3	**133.9**	169.5	106.4	**144.8**	183.3
RUBAVU	46.4	**63.6**	80.8	42.0	**57.6**	73.2	41.1	**56.7**	72.3	43.9	**60.5**	77.3
NYABIHU	86.1	**112.6**	139.0	61.4	**84.0**	106.6	59.9	**82.5**	105.2	64.4	**88.7**	113.1
NGORORERO	113.2	**152.8**	192.3	102.9	**140.3**	177.6	100.3	**137.7**	175.2	108.3	**148.6**	189.1
RUSIZI	142.9	**180.3**	217.8	83.7	**115.1**	146.5	81.5	**113.0**	144.5	88.0	**121.9**	155.9
NYAMASHEKE	211.5	**270.7**	329.9	173.9	**229.0**	284.2	169.0	**224.4**	279.9	183.6	**243.8**	304.1
RULINDO	68.2	**99.0**	129.9	68.2	**99.0**	129.9	66.4	**97.3**	128.1	71.7	**105.1**	138.5
GAKENKE	96.8	**141.3**	185.7	96.8	**141.3**	185.7	94.3	**138.7**	183.1	101.8	**149.9**	197.9
MUSANZE	62.2	**84.1**	106.0	45.0	**65.0**	85.0	44.0	**64.0**	84.0	46.9	**68.4**	89.9
BURERA	54.8	**78.6**	102.3	49.4	**71.7**	94.1	48.3	**70.7**	93.0	51.4	**75.3**	99.2
GICUMBI	108.0	**156.4**	204.7	107.8	**156.0**	204.2	104.9	**153.0**	201.2	113.5	**165.9**	218.2
RWAMAGANA	37.4	**47.8**	58.2	37.4	**47.8**	58.2	36.6	**47.1**	57.5	39.0	**50.1**	61.3
NYAGATARE	69.8	**86.7**	103.7	67.4	**84.1**	100.7	66.4	**83.1**	99.8	69.6	**87.1**	104.9
GATSIBO	71.4	**88.3**	105.1	67.7	**84.1**	100.5	66.1	**82.7**	99.3	70.8	**88.5**	106.4
KAYONZA	46.6	**56.2**	65.7	40.1	**48.8**	57.5	39.5	**48.2**	57.0	41.5	**50.7**	60.1
KIREHE	22.7	**27.1**	31.5	22.5	**26.9**	31.3	22.3	**26.8**	31.2	22.9	**27.4**	32.0
NGOMA	30.5	**38.4**	46.3	30.4	**38.3**	46.2	29.8	**37.8**	45.7	31.4	**39.8**	48.2
BUGESERA	48.1	**59.9**	71.6	47.9	**59.6**	71.4	47.4	**59.2**	70.9	49.0	**61.1**	73.3
Total Rwanda	**2,683**	**3,698**	**4,714**	**2,411**	**3,388**	**4,365**	**2,350**	**3,327**	**4,304**	**2,533**	**3,590**	**4,650**

[a] "Available" includes the mean annual increment (MAI) that is legally accessible, deducted of the annual sawnwood production.

Table A3.4: District-level supply/demand balance in 2009 ('000 tons, oven dry). The values reflect 3 productivity variants and the demand is limited to "conventional" woodfuels, excluding marginal wood products.

(kt od/year)		Available MAI			Estimated 2009 consumption of "conventional" woodfuels, excluding marginal wood products [a]			Balance 2009 based on revised demand		
		Low	**Medium**	High	Low prod	**Med. prod**	High prod	Low prod	**Med. prod**	High prod
District (2006)	**Code**	kt od	kt od	kt od	kt od	kt od	kt od	kt od	kt od	kt od
NYARUGENGE	101	13.6	**18.3**	23.1	314.2	**315.1**	316.0	-300.6	**-296.8**	-292.9
GASABO	102	39.3	**55.5**	71.8	457.7	**461.7**	465.7	-418.4	**-406.2**	-393.9
KICUKIRO	103	8.6	**11.6**	14.6	322.3	**322.3**	322.3	-313.7	**-310.7**	-307.7
NYANZA	201	61.4	**90.4**	119.4	102.5	**108.7**	115.0	-41.1	**-18.4**	4.4
GISAGARA	202	79.2	**115.7**	152.3	95.0	**104.6**	114.2	-15.8	**11.2**	38.1
NYARUGURU	203	249.9	**384.1**	518.3	103.9	**105.7**	107.5	146.0	**278.4**	410.8
HUYE	204	94.9	**144.9**	194.8	132.7	**138.7**	144.6	-37.8	**6.2**	50.2
NYAMAGABE	205	198.6	**293.0**	387.4	127.4	**128.3**	129.2	71.2	**164.7**	258.2
RUHANGO	206	49.5	**73.6**	97.7	98.6	**104.2**	109.9	-49.1	**-30.6**	-12.2
MUHANGA	207	100.8	**149.1**	197.5	135.7	**138.1**	140.6	-34.9	**11.0**	56.9
KAMONYI	208	69.0	**103.4**	137.8	81.5	**94.4**	107.3	-12.5	**9.0**	30.6
KARONGI	301	168.8	**230.6**	292.4	134.3	**137.6**	140.9	34.5	**93.0**	151.5
RUTSIRO	302	98.3	**133.9**	169.5	101.7	**108.4**	115.1	-3.4	**25.5**	54.4
RUBAVU	303	41.1	**56.7**	72.3	146.3	**147.8**	149.3	-105.3	**-91.1**	-77.0
NYABIHU	304	59.9	**82.5**	105.2	90.5	**99.2**	107.9	-30.6	**-16.6**	-2.7
NGORORERO	305	100.3	**137.7**	175.2	105.9	**117.2**	128.4	-5.6	**20.6**	46.8
RUSIZI	306	81.5	**113.0**	144.5	137.3	**142.0**	146.6	-55.8	**-29.0**	-2.1
NYAMASHEKE	307	169.0	**224.4**	279.9	137.0	**144.9**	152.9	32.0	**79.5**	127.0
RULINDO	401	66.4	**97.3**	128.1	79.5	**88.2**	96.8	-13.0	**9.1**	31.3
GAKENKE	402	94.3	**138.7**	183.1	102.7	**116.6**	130.5	-8.4	**22.2**	52.7
MUSANZE	403	44.0	**64.0**	84.0	126.1	**128.6**	131.0	-82.2	**-64.6**	-47.0
BURERA	404	48.3	**70.7**	93.0	85.3	**90.6**	95.9	-37.0	**-19.9**	-2.8
GICUMBI	405	104.9	**153.0**	201.2	168.5	**179.5**	190.6	-63.6	**-26.5**	10.6
RWAMAGANA	501	36.6	**47.1**	57.5	88.5	**90.6**	92.7	-51.9	**-43.5**	-35.2
NYAGATARE	502	66.4	**83.1**	99.8	117.5	**118.7**	119.9	-51.1	**-35.6**	-20.0
GATSIBO	503	66.1	**82.7**	99.3	118.7	**121.5**	124.3	-52.6	**-38.8**	-25.0
KAYONZA	504	39.5	**48.2**	57.0	79.1	**79.6**	80.2	-39.6	**-31.4**	-23.2
KIREHE	505	22.3	**26.8**	31.2	78.1	**78.1**	78.2	-55.8	**-51.4**	-47.0
NGOMA	506	29.8	**37.8**	45.7	84.4	**84.4**	84.5	-54.6	**-46.7**	-38.8
BUGESERA	507	47.4	**59.2**	70.9	100.2	**101.3**	102.4	-52.8	**-42.1**	-31.5
Rwanda	**Total**	**2,350**	**3,327**	**4,304**	**4,053**	**4,197**	**4,340**	**-1,704**	**-870**	**-36**

[a] Different "conventional" woodfuel demand are estimated, depending on the productivity variant assumed, as the fraction of conventional fuelwood use in rural areas is expected to change in case of a higher, or lower, local availability of conventional wood resources.

ANNEX 4: ANALYSIS OF AREAS WITH SLOPE OVER 55% POTENTIALLY SUITABLE FOR NEW FOREST PLANTATIONS

The land use of Rwanda is very intensive, due to the high population density and to the high farming suitability, in spite of its rolling landscapes. There is therefore limited unused area that could be devoted to new forest plantations where farming has not yet established. But Rwanda is also a landslide-prone country due to prevailing slope and geologic characteristics; in such environments plantations provide suitable soil protection on steeper slopes, combining important protective and productive functions. In practice, steeper slopes are the only significant land portions where plantations can be established with limited competition with farming and actually supporting farming by preventing soil erosion.

Government directives in the framework of Vision 2020 indicate that all slopes above 55% should be planted up as soon as possible in the effort of combining soil protection and increasing sustainable woodfuel production. The question is: How much land with slope above 55% exists that is not yet occupied by forest plantations or by (intensive) farming? In order to answer this question, a GIS analysis was done combining digital elevation data and forest cover data.

The first issue was to map the land areas above 55% slope and to determine its surface and distribution. This is not as simple and univocal as one may think. In fact, in a finely rolling landscape the slope varies in a matter of few meters and the surface "above 55%" varies with the resolution of the terrain model, as shown in Table A4.1. The analysis was done at two different resolutions, 10m and 50m, which produced quite different results.

But resolution affects also the planning and planting process. It appears unrealistic to plan the creation of innumerable lots of few hundred m² in the middle of agricultural fields. The slope map at 10m resolution shows a large surface with slope above 55% but this area is composed of a myriad of tiny slopes (56% of the area below ¼ of ha). With a lower resolution of analysis of 50m, the surface shrinks to 128 or 103 thousand ha, depending on the original dtm used. These surfaces are composed by units of at least ¼ of ha, which makes them more easily identifiable in the field and more "manageable" under all perspectives.

Table A4.1: Estimated area above 55% slope based on different digital terrain models (dtm) and resolution of analysis

Resolution of digital terrain model	Source of dtm	Surface above 55% slope (ha)	Remarks
10m	Orthophoto 2009	292,000	Too detailed for operational planning of conventional plantation (56% of area below ¼ ha size) but useful for agro-forestry activities
50m	**Based on 50m-focalmean of 10m dtm based on Orthophoto 2009**	**128,000**	**Preferred dataset for operational planning of plantation and further land use analysis.**

The second issue was to identify the current land cover of these areas and to quantify and locate the areas with slope above a given value (i.e. 55%) that are not planted already. The area *potentially suitable* for new planting was defined as the land area with slope above 55% that is not covered by natural vegetation and not already planted. The results of this analysis are shown in Table A4.2.

At resolution of 50m (cell of 0.25 ha) there are some 52,000 hectares, out of 128,000 hectares, that are not protected and *potentially suitable* for new plantations. Additional 1,582 hectares are located in protected areas. These areas are mostly located in Western, Northern and Southern Provinces.

At 10m resolution (cell of 0.01 ha) the *potentially suitable* area increases to 137,900 hectares, with additional 5,100 hectares located in protected areas. Given the small size of the slope areas detected with 10m resolution, good part of this area is probably unsuitable to conventional plantations or even woodlots.

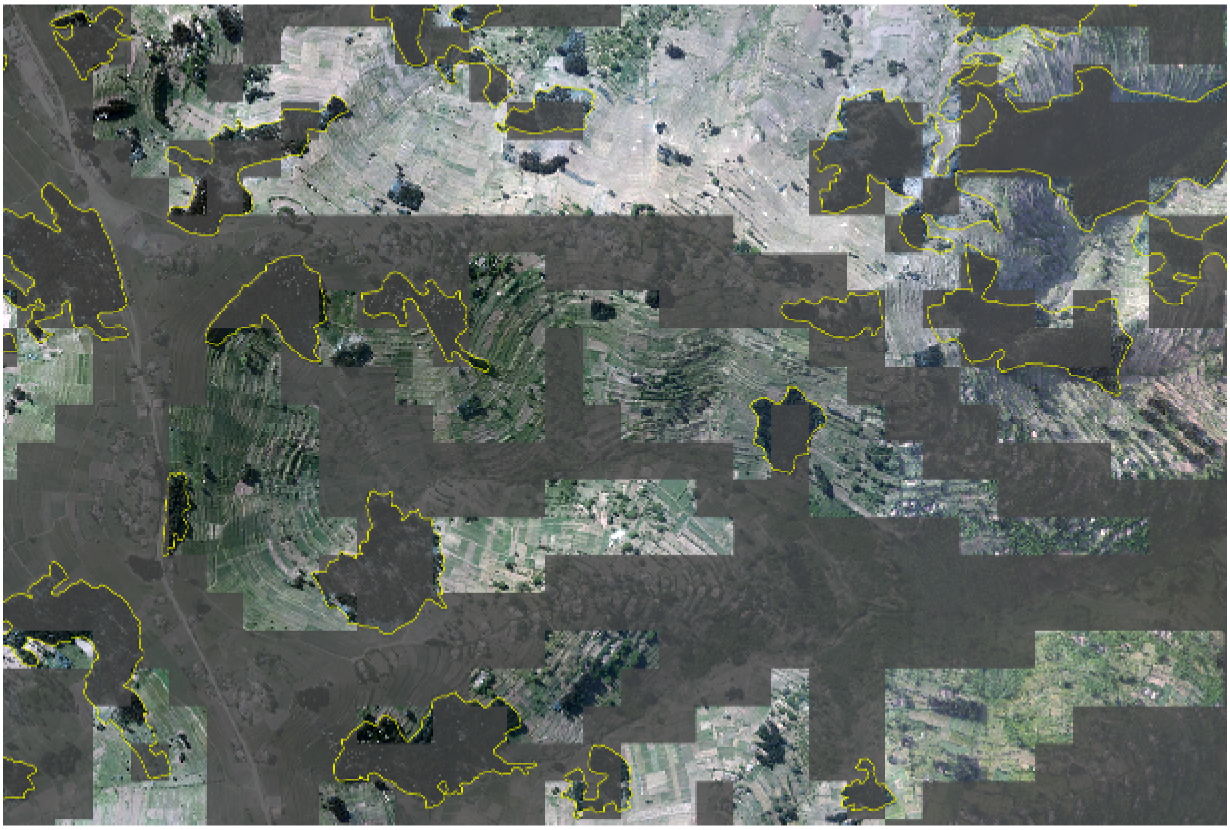
However, the results of this analysis can be used to delineate the areas where agroforestry must play a more powerful role, in order to promote soil protection through a more diffuse tree cover.

Table A4.2: Lands with slope above 55% *potentially available* for new plantation areas (ha).

		Values=ha			non-forest land >55%slope @ 50m resolution		non-forest land >55%slope @ 10m resolution	
Province	code	Dist06_name	**Total area**	**Plantation area 2009**	Non-protected	In protected area	Non-protected	In protected area
	101	**NYARUGENGE**	13,398	2,448	134.8		434.0	
	102	**GASABO**	42,922	6,763	422.0		1,349.0	
	103	**KICUKIRO**	16,673	1,059	1.5		19.8	
Southern	201	**NYANZA**	67,216	7,130	205.8		874.5	
	202	**GISAGARA**	67,922	8,154	135.3		971.0	
	203	**NYARUGURU**	101,019	26,840	963.0	4.3	5,488.0	36.0
	204	**HUYE**	58,158	11,496	174.3		863.8	
	205	**NYAMAGABE**	109,040	28,319	2,825.0	1.0	10,684.8	8.8
	206	**RUHANGO**	62,683	6,851	135.0		986.5	
	207	**MUHANGA**	64,766	13,594	3,055.3		8,310.0	
	208	**KAMONYI**	65,551	7,603	403.5		1,404.5	
Western	301	**KARONGI**	99,309	19,288	3,216.8		11,777.3	
	302	**RUTSIRO**	113,542	9,727	2,717.5	654.3	9,514.8	2,411.3
	303	**RUBAVU**	38,784	2,998	648.3	124.8	1,910.3	158.0
	304	**NYABIHU**	53,133	6,898	3,618.8	359.5	7,296.8	1,103.8
	305	**NGORORERO**	67,895	10,814	4,818.5	203.3	13,293.5	844.8
	306	**RUSIZI**	94,656	8,294	3,652.5	160.0	5,215.3	262.3
	307	**NYAMASHEKE**	117,359	17,877	3,012.8	7.8	11,097.8	67.8
Northern	401	**RULINDO**	56,696	12,005	3,689.8		6,938.8	
	402	**GAKENKE**	70,408	14,877	6,800.3		14,524.5	
	403	**MUSANZE**	53,025	5,101	1,056.0	3.8	2,729.5	136.0
	404	**BURERA**	64,445	6,272	4,857.5	1.5	8,373.5	40.8
	405	**GICUMBI**	82,955	16,451	3,860.0		8,429.5	5.3
Eastern	501	**RWAMAGANA**	68,201	5,354	58.8		403.5	
	502	**NYAGATARE**	192,131	7,364	552.8	61.8	1,235.5	11.8
	503	**GATSIBO**	158,017	9,791	516.0		1,563.5	2.8
	504	**KAYONZA**	193,443	4,453	168.8	0.3	719.8	13.5
	505	**KIREHE**	117,991	1,513	204.5		742.0	
	506	**NGOMA**	86,772	3,926	76.3		709.8	
	507	**BUGESERA**	129,039	3,540	0.8		50.5	
			2,527,147	**286,797**	**51,982**	**1,582**	**137,912**	**5,103**
Provincial summary								
Kigali City			72,993	10,270	558	0	1,803	0
Southern			596,354	109,986	7,897	5	29,583	45
Western			584,678	75,895	21,685	1,510	60,106	4,848
Northern			327,528	54,706	20,264	5	40,996	182
Eastern			945,594	35,940	1,578	62	5,425	28
			2,527,147	**286,797**	**51,982**	**1,582**	**137,912**	**5,103**

It is obviously unrealistic to assume that these areas are all available for planting. In fact, in a subsequent phase of analysis the current land use and ownership of these areas must be reviewed in great detail in order to identify truly feasible plantation areas. At present a detailed land use map is not yet available for Rwanda and the cadastral data is still in progress. However, since the *potentially suitable* areas cover a limited surface, it seems feasible and relatively rapid to produce an ad-hoc land use map of these areas on the basis of the 2009 orthophoto coverage. Similarly, ownership details may be extracted for these areas, at least for the regions where cadastral data already exist. A preliminary reconnaissance of the areas, however, indicates that good part of these steep slopes are under intensive farming on terrace systems, as in the example shown in Figure A4.1. Conventional plantations seem inadequate for these situations, given the intensive land use, but agro-forestry and small-scale woodlots can certainly be increased in such steep areas without compromising farm production.

Figure A4.1: Example of intensive terrace farming in areas with slope above 55% (Musanze District).



Note: Visible orthophoto areas have slopes of 55% or greater. Grey-shaded areas have more gentle slopes and/or are already planted (pixel size 50m). Plantations above ¼ ha are outlined in yellow.

ANNEX 5: VALUE CHAINS OF CHARCOAL AND FUELWOOD TRADED IN KIGALI AND IN OTHER MAIN URBAN AREAS

Methodology

The methodology for value chain analysis has been participatory and involved key informers: charcoal producers, transporters dealers, charcoal intermediaries, local authorities, other stakeholders in the sector, key ministries, government bodies in charge of forest, environment and energy, etc. Quantitative and qualitative data were collected from documentation review and field work. Questionnaires, Focus Group Discussions (FGDs), interviews, direct observation, charcoal weighting have been applied to collect the primary data. Six phases were followed to conduct the analysis:

1. Inception
2. Desk study of relevant documents
3. Data collection tool design
4. Field work
5. Data compilation and interpretation
6. Report writing

Inception

Before the beginning of the field work a letter of consent from the Ministry of national resource and National institute of statistics was obtained. The research team identified afterward and contacted the targeted informants.

Desk study of relevant documents

The documentation review helped in understanding the evolution of energy consumption patterns, market conditions, value chains, economic relevance and evaluating alternative taxation regimes in Rwanda. The consultant team listed and carefully reviewed all possible sources of existing data. Among the studies that were examined in order to acquire reference values on woodfuel consumption and trends and other information, are the documents which can be found in the list of references.

Data collection tool design

Three data collection tools were designed by the consultant team to collect primary data. These include:

- Semi-structured questionnaire and FGD guidelines for charcoal producer(s);
- Semi-structured questionnaire for charcoal transporter(s);
- Semi-structured questionnaire for woodfuel dealer(s);

Field work

a) Sampling

The Fuelwood and Charcoal value chain analysis focused on the urban areas of Kigali city and other urban areas and the most important producers Districts.

For selling places

The analysis for Fuelwood and Charcoal selling targeted the urban parts of Kigali City (Gasabo, Kicukiro and Nyarugenge Districts), Huye town in Southern province, Rubavu in Western province, Musanze in the Northern Province and Rwamagana in the Eastern province. 105 dealers located in 17 sectors of

Kigali city were interviewed and 18 from other urban areas were interviewed. Most of charcoal dealers interviewed were located in the big markets of the respective towns. The table below show the number of charcoal dealers interviewed in each town.

Table A5.1: number of charcoal dealers interviewed in each town

	District	Number of interviews done	% of interviews done in each District
Kigali City	GASABO	38	31
	KICUKIRO	41	33
	NYARUGENGE	26	21
	Sub-Total	**105**	**85**
Other urban areas	HUYE	6	5
	MUSANZE	3	2
	RUBAVU	7	6
	RWAMAGANA	2	2
	Sub-Total	**18**	**15**
	Total	**123**	**100**

<u>For production places</u>

For woodfuel and charcoal production, 5 Districts (Ngororero, Nyaruguru, Nyamagabe, Gicumbi et Rusizi) which are big producers of charcoal in the country[25] were visited and charcoal producers and local authorities interviewed.

Fuelwood and charcoal producers and dealers were selected randomly and 17 charcoal producers or their associations were interviewed in each District. Additionally, a focus group discussion of 25 charcoal producers from 5 Districts was conducted.

b) <u>Field data collection</u>

The data was collected by the consultancy team using the designed tools. Bags, tins/buckets of charcoal were weighted both at the production and selling place in order to increase precision in the estimate of volume for the different products of the value chain.

Data compilation and analysis

Based on the structure of the questionnaires, 3 SPSS matrixes were designed in order to compile primary data from different key informants. Primary data has been analysed using SPSS routines and interpreted; the results were compiled and presented in this report. A separate database produced in SPSS format was handed over with the report. The information from previous studies related to the subject has been also used to complete or cross-check primary data. The analysis of all this information formed the basis for the formulation of the conclusion and recommendations hereafter discussed.

[25] MININFRA, 2008. BEST Report

Production, trading and retailing organization

a) Charcoal and Fuelwood production

Woodfuels[26], particularly fuelwood and charcoal, are the most important sources of energy for households as well as for many industrial, commercial and public sector users. Fuelwood and charcoal are produced from trees' woody biomass that in the case of Rwanda comes primarily from Eucalyptus plantations and woodlots, with contributions from farm trees and shrubs.

The harvesting of trees used either as fuelwood or charcoal and charcoal production are subjected to the approval of government authorities in charge of forests at different levels and depend on the size and ownership of the plantation. More details on administrative requirement for tree harvesting and charcoal production are discussed elsewhere in this report.

All 42 charcoal producers visited (17 interviewed and 25 participating in a focus group discussion) during the survey, located in Gicumbi, Ngororero, Nyamagabe, Nyaruguru, and Rusizi, use traditional charring techniques. Among them 8 combined traditional techniques with improved ones. Given the fact that charcoal is produced primarily with traditional techniques, the conversion rate of wood to charcoal is still low. In the absence of solid references on the current carbonization rates in Rwanda, the value of 12% has been considered representative of the current situation (Kammen and Lew, 1995; BEST; Murererehe, personal communication) and applied for the present analysis. In general, it appears that the diffusion of improved charring techniques is somehow limited by the reaction of wood and charcoal producers to tree cutting regulations, as discussed further below.

b) Charcoal and Fuelwood Collection

– *Packaging and loading*

Charcoal is packaged in the same bags as used for transporting approximately 100 kg of grains (beans). Weight measurements carried out on 9 large markets of Kigali, 4 other large towns and 59 small shops indicate that the weight of one bag is 43.7 and 43.5 kg on average respectively in Kigali city and other urban areas, as shown in Table A5.2 .

Table A5.2: Weight of a bag of charcoal

			Confidence Interval at 95%probability	
		Mean	Lower limit	Upper limit
	Sample size (-)	kg	kg	kg
Kigali	105	43.6	42.6	44.7
Other urban	18	43.5	40.7	46.3
Total	**123**			

Source: Field survey

Fuelwood sold in Kigali city and other town for household consumption is mainly packed in bundles of around 15 kg on average while fuelwood for used for industrial and commercial purposes is measured in

[26] According to the definitions of the FAO Unified Bioenergy Terminology (FAO, 2004):

Woodfuels are "all types of biofuels originating directly or indirectly from woody biomass (includes fuelwood, charcoal and black liquor)".

Fuelwood is "a woodfuel where the original composition of the wood is preserved (including wood in the raw and residues from wood processing industries)".

Charcoal is "the solid residue derived from carbonization distillation, pyrolysis and torrefaction of fuelwood".

steres and sold by truck or van. Non-commercial fuelwood collected by household's members (children in most of cases), are packed in bundles of 5 to 9 kg.

– *Collection centers/points*

Charcoal and commercialized fuelwood are firstly brought to roadsides accessible to vehicles. The location of collection points depends on the fuelwood and charcoal production places at a given time. The collection points for charcoal are mostly unsheltered places and in few cases charcoal is just covered by simple plastic sheeting. The charcoal producer has to transport on head his merchandise up to the nearest accessible road. The distance covered by both charcoal and fuelwood producers to reach the roadside varies from 0.2 km to 5km. The charcoal and fuelwood producers watch their products up to their loading in trucks that transport them to the selling places and clients.

Non-commercial fuelwood is directly transported from the forest to the households. Commercial fuelwood used for satisfying household or restaurant cooking needs is collected by individuals or businessmen, who bring them directly to the client without intermediaries of dealers. Non-commercial fuelwood for rural households consumption is mainly collected by children and women from the surrounding forests and farmlands, including varying proportions of deadwood, twigs and pruning of living trees and shrubs.

Commercial fuelwood used for satisfying household or restaurant cooking needs is collected and/or transported by businessmen or other people who do these activities occasionally. The main source of commercialized fuelwood are forest plantations at the time of harvesting and thinning, or felling of individual trees. Commercial fuelwood usually include stems and branches of felled trees.

– *Collection process*

Charcoal and commercial fuelwood producers are in direct contact with the client (final consumer), distributors and commissionaire (who works for distributors) before, during and after the production. Commissionaires and distributors are well informed on who is cutting / carbonizing her/his forest; and they are well known in the production areas.

Charcoal may be collected at the production site in two stages. In the first stage local businessmen, collect charcoal from the producers and at the second stage they sell it to the distributors (resident or non-resident) who bring it to big towns or to the clients. The time needed by the charcoal and fuelwood producer to sell its products varies from one day up to a month depending on the season and condition of the roads.

c) Charcoal and fuelwood transportation and distribution to selling places

In Kigali city and other urban areas, charcoal is transported and distributed by businessmen directly from the production sites to dealers/retailers located in towns who sell it to final consumers. Charcoal transportation is done primarily by trucks with 10-tons capacity that carry 150 to 220 bags of charcoal and by vans with 4-tons capacity that carry 80 to 100 bags. In other towns and in the outskirts of Kigali, consumers and dealers can get charcoal from small charcoal producers who transport it on head or by bicycle directly from production places. The selling points in Kigali and in other towns are markets, charcoal storages and shops which combine charcoal and fuelwood business with other businesses.

Charcoal dealers cooperatives

Charcoal and fuelwood dealers are not regrouped in active formal cooperatives though they usually have structures allowing them to pay collectively the rent of the working place, District taxes and royalties, guards and cleaning fees. This reduces significantly the individual cost paid for charcoal and fuelwood selling and strengthens their power of negotiation with landowners and local authorities concerning working conditions.

Fuelwood for urban households' consumption is distributed by small wood producers and dealers from the neighborhood of the town. Fuelwood used for commercial and industrial purposes is distributed by businessmen from the Districts where the consumers are located or in the neighboring ones. Large consumers such as tea factories, schools, and religious institutions have, in many of cases, their own plantations and buy only the fraction beyond their production capacities.

The average number of trips done by each charcoal distributor is estimated at 8 trips per month with each trip lasting approximately two days. Each distributor carries to the market or consumption site, an average of 1,600 bags of charcoal per month.

d) Pricing at production and selling place

The supply price of charcoal is fluctuating in the course the year depending on seasons/weather (rainy or dry), and on production places, and depends on seasonal and non-seasonal restrictions regarding its production and transportation. The distributors control the price of charcoal because they are between producers and sellers. Distributors and middle men (commissioners) tend to lower the price paid at the production site and increase it at the selling place on the pretext of risky high transportation cost especially during the rainy season. Charcoal and fuelwood producers wait longer before selling their products and are forced, sometimes, to sell charcoal at lower prices because few transporters are accessing the production areas.

Even if the dealers and producers could know by the means of phone, the price at production and selling places, they are generally not able to control the price of charcoal due to lack of organization, professionalism and capital by both dealers and producers to invest in transportation means. Other factors such as distance covered by distributors and road conditions have a significant impact on charcoal price in certain periods. The price of fuelwood also fluctuates during the year though to a more limited extent compared to charcoal due to the fact that its demand for cooking purposes is limited to a relatively small number of urban consumers.

e) Charcoal and fuelwood selling units and price

The most common selling units for charcoal are bags and buckets/tins. A bucket/tin holds approximately 1.4 kg of charcoal. Table A5.3 provides the prices of charcoal paid by different key actors of the value chain.

The price of charcoal is higher in other towns as compared to Kigali and this is due to the price of charcoal in the neighboring countryside and distance made to reach a specific town. In Rusizi and Rubavu, the price of charcoal goes up because consumers[27] from neighboring towns of DRC (Bukavu and Goma) pay a higher price. In Rwamagana town, the price of charcoal is also high due to the fact that it is located where production is very low; the charcoal sold in this town, therefore, travels a long distance from either Kigali or remote areas of Kayonza, Kirehe, Ngoma and Nyagatare Districts.

Table A5.3 : Prices of charcoal

Place	**Prices Paid by**			
	Final consumer to dealer		**Dealer to distributor**	**Distributor to charcoal producer**
	Per bag	*Per bucket/tin*	*Per bag*	*Per bag*
Kigali city	7,200	200	6,100	4,200
Other towns	7,700	160	6,600	4,200

Source: Primary data

[27] The trans-border business of charcoal is informal and the quantities bought are mostly transported on head or bicycle.

The prices used for this analysis are the market price of the time of the survey; April-May 2012

The selling unit for firewood for household use is a bundle of 15 kg on average while the selling unit for commercial and industrial use is a stere or a truck. The cost of bundle of 15kg of commercial fuelwood for household's usage is estimated to RWF 1,500 in Kigali city and other towns and RWF 500 in rural areas.

Value of non-commercialized fuelwood in rural area

The value of non-commercialized wood is estimated based on the following assumptions:

1. Non-commercial Fuelwood includes marginal wood products such as deadwood and twigs collected for free from private, public or District tree plantations as well as pruned branches from farm trees and shrubs.
2. Fuelwood is often collected by children and the quantity collected for a trip is estimated at 5kg.
3. The time needed for fuelwood collection is estimated to 2 hours.
4. The price of commercialized wood in rural areas is RWF 500 for a bundle of 15 kg, which makes RWF 33 per kg including production, cutting, packing and transportation to the roadside before selling.
5. In case of commercialized fuelwood, cost of collection is valued to 25% of its price, which makes RWF 8 per kg. This is the price used for calculating the value of non-commercialized fuelwood in rural areas.

The price of a stere of fuelwood varies from RWF 3,000 to 9,000 with average price estimated to RWF 6,000 while the price of a truck of wood varies from RWF 150,000 to 180,000.

Wood used for purposes other than cooking is mostly sold per piece depending on the diameter of the trunk. Trees used for construction purposes vary from RWF 1,000 to 3,000 while trees used for timbers production cost between RWF 5,000 to 15,000.

Costs and profit for charcoal and fuelwood value chain

This section focuses on the analysis of cost and profit of charcoal only because the number fuelwood users in urban area of Kigali and other towns is insignificant. The cost and profit analysis of fuelwood production has been done per hectare of plantation while the analysis for charcoal is based on the ton of charcoal produced. This section analyzes separately the cost and profit for wood and charcoal production, charcoal distribution and selling.

a) Costs and profit for wood production

– *Cost for wood production*

The cost of a seedling is estimated at RWF 28 and the number of trees planted on a hectare at 1,600. The total amount needed to produce one ha of plantation, including planting, maintenance and land value is estimated to RWF 431,052, as summarized in Table A5.4.

Table A5.4: Production cost of wood for 1 ha

Cost for 1 ha of plantation	**Unit**	**Quantity**	**Unit cost** (RWF)	**Total cost** (RWF)
Seedlings	Piece	1,600	28	45,052
Plantation	Man-day	206	1,000	206,000
Maintenance	Man-day	60	1,000	60,000
Total for plantation and maintenance excluding land value				**311,052**
Land for 8 years	Year	8	15,000	120,000
Total for plantation and maintenance of 1 ha including land value				**431,052**

Source: Estimation done based on ISAR data, IFDC and forest experts

– *Profit from wood used for charcoal production*

According to charcoal producers, the wood needed to produce one ton of charcoal costs RWF 52,961, on average (see further section b)). From Table A5.4 above we see that the cost for one hectare of plantation of 8 years is 431,052 RWF.

Given these two cost items, the profit for wood producers depends on the productivity of the plantation:

- Assuming a Low productivity[28] of 11.2 m^3 ha^{-1} yr^{-1} or 7.9 tons of woody biomass (dry matter) and 8 years rotation, 0.108 hectares of plantations are needed to produce the wood necessary for one ton of charcoal. In this case wood production cost (for 1 ton of charcoal) is 24,233 RWF and thus the profit is 28,728 RWF.
- Assuming a High productivity variant[29] for well-managed plantations, the productivity would rise to 21.4 m^3 ha^{-1} yr^{-1} or 15 tons of woody biomass; for 8 years rotation, 0.057 hectares of plantations are needed to produce the wood producing one ton of charcoal. In this case wood production cost would be 12,715 RWF and thus the profit would increase to 40,246 RWF.
- Assuming a more realistic Medium productivity variant[30], the production would be 16.3 m^3 ha^{-1} yr^{-1} or 11.4 tons of woody biomass; with 8 years rotation, 0.075 hectares of plantations will produce the wood needed for one ton of charcoal. Wood production cost would be 16,678 RWF and the profit will rise to 36,283 RWF.

Table A5.5 presents costs and profits of wood production estimated assuming for each plantation created 3 rotations of 8 years and 3 rotations of 5 years.

[28] Low productivity variant for the Southern and Western Provinces, based on 2007 ISAR inventory results elaborated in FAO WISDOM study (Drigo and Nzabanita, FAO, 2011).

[29] High productivity variant for the Southern and Western Provinces based on SEW-IFDC inventory results.

[30] Midrange between Low and High productivity variants

Table A5.5: Cost and Profit for wood used for charcoal production assuming 3 rotations of 8 and 5 years for each plantation and Low, Medium and High productivity variants

	Unit	Productivity of plantations		
		Low productivity	***Medium productivity***	***High productivity***
Productivity of plantation (MAI)	m^3 ha^{-1} yr^{-1}	11.2	16.3	21.4
Assuming a system with 3 rotations of 8 years				
Area of plantation needed for one ton of charcoal	Ha	0.108	0.075	0.057
Cost of wood production for one ton of charcoal	RWF	24,233	16,678	12,715
Amount paid by charcoal producers for the raw wood	RWF	52,961	52,961	52,961
Profit of wood producer (per ton of charcoal)	RWF	**28,728**	**36,283**	**40,246**
Assuming a system with 3 rotations of 5 years				
Area of plantation needed for one ton of charcoal	Ha	0.173	0.119	0.091
Cost of wood production for one ton of charcoal	RWF	30,972	21,317	16,251
Amount paid by charcoal producers for the raw wood	RWF	52,961	52,961	52,961
Profit of wood producer (per ton of charcoal)	RWF	**21,989**	**31,644**	**36,710**

Source: Estimated from data collected from charcoal producers and supply module analysis

b) Cost and profit for charcoal production

Costs for charcoal production

The costs paid by the charcoal producer include the cost of wood, tree cutting permit, other taxes and royalties paid to the District (production) and manpower. Charcoal is produced occasionally due to the limitation of tree cutting permits delivery, amounting to one permit per charcoal producer per month. All costs for charcoal production were estimated per tree permit delivered to a charcoal producer.

- *Cost of wood needed for charcoal production*

Based on the data collected from interviews and focus group discussion of 42 charcoal producers located in Rusizi, Nyamagabe, Nyaruguru, Gicumbi and Ngororero Districts, the number of bags of charcoal produced and sold per producer for each round (a single tree-cutting permit) is estimated at 66 bags on average (48 - 85 at 95%) which correspond to 2,904 kg (2,100 - 3,700), considering a bag of 44 Kg as weighted at the selling points of Kigali and other urban areas. Based on a conversion rate of wood to charcoal of 12%, the quantity of wood needed for the production of 2,904 kg of charcoal is estimated to be 24,200 kg of wood. Charcoal producers reported that they pay on average of RWF 153,800 for wood for each round (for each tree cutting permit delivered). In other words they pay RWF 153,800 to get the raw material, wood, needed to produce 2,904 kg of charcoal on average. This means that the cost paid to the wood producer for the production of a ton of charcoal corresponds to RWF 52,961 (153,800*1,000/2904).

- *Cost of manpower needed for charcoal production*

The charcoal producers interviewed indicated that charcoal production includes 7 main activities: Cutting trees/packing, kiln set-up and follow-up, drawing charcoal from the kiln, cooling charcoal, charcoal collecting, bags loading, and transportation of bags to the road side.

The cost for manpower depends on the region and specific activities done. The manpower for tree cutting and kiln packing is paid more than that used for charcoal collection or bag packing. Manpower from remote areas is cheaper that the one located alongside the main road. Cost of manpower also varies depending on the slope of the land where charcoal is being produced.

Four main methods for paying manpower were identified during the survey : payment per bag produced and sold, as percentage of charcoal produced, per day and per task.

Payment system of charcoal production

Payment per bag produced

Payment per bag produced consists of paying the charcoal producer a fixed amount per bag produced and sold. This method is mostly used by wood owners who do not have the time nor the skills to produce charcoal themselves. The payment per bag varies from RWF 500 to 1,200 depending on the distance between the road and the production area.

Payment per percentage of charcoal produced

This method is used by small wood or charcoal producers who pay their colleagues to help them in the production of charcoal. In this case, the charcoal producer / wood owners or "charcoal producers-Businessman" take the first 20 to 30% of the value of the charcoal produced for themselves, as a compensation for the cost of wood, tree cutting permit, taxes and royalties, and share equally the remaining 70 to 80 % of the production with the colleague who assisted in the charcoal production.

Payment per day

Payment per day is used when charcoal is produced at large scale and the charcoal producer has the time for supervision. The daily pay varies from RWF 1,000 to 1,200 depending on the task and the region.

Payment per task

This system is used for some specific tasks for charcoal production such as charcoal collection and bag loading. Sometimes, the manpower for tree cutting is also paid per tree cut and packed.

For charcoal value chain analysis, the manpower payment is estimated per day and the average daily payment for different charcoal producing activities is valued to RWF 1,050. The total number of man-days needed for the production of 2,904 kg is estimated at 66 and the total cost paid to manpower for charcoal production at RWF 69,300. Table A5.6 shows the number of man-days needed for each charcoal producing activity, in order to produce 2,904 kg and one ton of charcoal.

Table A5.6: Manpower for charcoal production

	Cost of Manpower for the production of				
	2,904 kg of charcoal				***Per ton of charcoal (RWF)***
Activity	*Unit*	*Quantity*	*Unit cost (RWF)*	*Total cost (RWF)*	
Cutting trees/packing	Man-day	18	1,050	18,900	6,508
Kiln set-up and keeping	Man-day	8	1,050	8,400	2,893
Drawing charcoal from the kiln	Man-day	3	1,050	3,150	1,085
Cooling charcoal	Man-day	2	1,050	2,100	723
Charcoal collecting	Man-day	13	1,050	13,650	4,700
Bags loading	Man-day	6	1,050	6,300	2,169
Transporting Bags to the road side	Man-day	16	1,050	16,800	5,785
Total		**66**		**69,300**	**23,864**

Source: Primary data collected from charcoal producers

- *Taxes and royalties for charcoal production*

The cost of a tree cutting permit varies from one District to another and it is paid by the charcoal producer. Details on the requirements and cost for tree cutting permit delivery are discussed under the Section dealing with administrative requirements.

In most charcoal producing Districts (Nymagabe and Nyaruguru), the cost of a tree cutting permit varies from RWF 10,000 to 15,000 while in the other Districts is between 1,200 and 5,000. The average amount paid for a tree cutting permit is estimated at RWF 5,700 and RWF 1,963 per ton of charcoal produced. The amount paid for a tree-cutting permit includes 1% of the estimated value of the plantation or a fixed amount decided by the District that goes to the national forest fund.

Even if the charcoal production is an occasional activity for producers, this activity is subjected to the seasonal payment of royalties decided by the District council and varies from District to District and in time. The amount to be paid can include a fixed contribution to basic education, to District football teams or any other contribution requested by local authorities to every businessman. The amount of other taxes and royalties paid is estimated at RWF 16,000 (12,400 - 19,500) per round of charcoal production and RWF 5,510 (4,300 - 6,700) per ton of charcoal produced.

Given the rigidity of the whole process and the difficulties to afford the cost of tree cutting permit, some wood owners opt for clandestine tree cutting and charcoal production. This significantly affects the quality and quantity of charcoal produced because wood is not dried adequately and the supervision of the charring process is poor. The measures and regulations are perceived by both wood and charcoal producers as constraints to the access to raw material for charcoal production.

– *Profit from charcoal production*

The price of charcoal paid by the distributor to producer at the production place is estimated at approximately RWF 4,200 (3,900 - 4,700) per bag of 44 kg. The average number of bags produced for a single tree-cutting permit is estimated at 66, with a total weight of 2,904 kg. This means that the total value of the sales from the charcoal production associated with a single tree cutting permit is RWF 277,200 corresponding to RWF 95,455 per ton of produced charcoal, as shown in Table A5.7.

Table A5.7: Cost and Profit from charcoal production

	Production cost (RWF) for					**Sales (RWF)**	**Profit (RWF)**
Quantity of charcoal produced	*Wood*	*Manpower*	*Tree cutting permit paid*	*Taxes and royalties*	*Total*		
66 bags (2,904 kg)	153,800	69,300	5,700	16,000	244,800	277,200	32,400
One ton	52,961	23,864	1,963	5,510	84,298	95,455	11,157

Source: Primary data collected from charcoal producers

The profit earned by charcoal producers is estimated at RWF 32,400 per charcoal production round and RWF 11,157 per ton of produced charcoal.

c) Cost and profit for charcoal distribution

Costs associated with charcoal distribution can be classified into three main categories; cost of charcoal, taxes and royalties paid both to the production and selling Districts and direct expenses other than taxes.

The cost analysis for charcoal distribution is done based on the average quantity of transported charcoal per month which is estimated at 1,600 bags of 44 kg; or 70,400 kg of charcoal. Given the purchasing price paid by the dealer to the distributor (RWF 8,642,200 per month, or RWF 122,7 per kg), the total value of distributed charcoal per month amounts to about RWF 9,760,000, which corresponds to RWF 138,636 per ton.

The cost associated with the distribution of this quantity of charcoal includes the purchase price of charcoal from the producer, taxes and royalties paid both to the production and selling Districts and direct costs for the transportation.

– ***Cost of charcoal paid by the distributor***

Given the price of a bag of charcoal paid by the distributor to the producer, the value of transported charcoal per distributor equals to RWF 6,720,000 per month and RWF 95,455 per ton.

– ***Taxes and royalties paid to the production District by the distributor***

Taxes and royalties paid by the distributor for charcoal transportation includes a charcoal transportation permit, a *patent*, loading tax, per bag tax and contribution to different development activities.

The distributor has to get the *patent* before requesting the charcoal transportation permit. The patent is paid on annual basis within each district she/he would like to transport charcoal. Distributors report that they pay between RWF 40,000 and RWF 60,000 and the annual average amount paid for patent is RWF 42,000 which corresponds to RWF 3,500 per month. The cost of a charcoal and other woody products transportation permit differs from District to District. It varies from RWF 6,000 to 50,000 and its average cost is estimated at RWF 38,600 for a period of one month.

The distributors also pay a fixed tax per bag loaded and loading royalties. The tax per bag is paid for each bag transported while the loading tax is paid per loading round in each sector. The tax per bag varies from RWF 100 to 200 and the average amount of per bag tax is estimated at RWF 150. An average of RWF 30,375 is paid per trip and RWF 243,000 per month.

The distributor also pays RWF 25,000 for loading royalties in almost all Districts. However, in a few Districts, the cost of loading royalties is RWF 15,000. Therefore the average amount paid for loading royalties is estimated at RWF 24,013 per round and RWF 192,100 per month.

Table A5.8: Taxes and royalties paid for transported charcoal to the production District

Type of tax and royalties	Amount (RWF) paid for transported charcoal	
	For 70,400 kg (average amount transported in one month)	*Per ton*
Patent	3,500	50
Transportation permit	38,600	548
Per bag Tax	243,000	3,452
Royalties for loading	192,100	2,729
Total	**477,200**	**6,778**

Source: Primary data collected from charcoal distributors

– ***Taxes and royalties paid to the selling District by the distributor***

Unloading royalties and cleaning fees are the only royalties paid by the charcoal distributor to the selling District and are paid to each unloading site. The total amount paid per trip depends on the number of sites the distributor unloads her/his merchandise. The amount paid for unloading royalties varies from RWF 1,000 to 2,000 with average amount paid being estimated at RWF 1,580 per trip. Cleaning fees vary from RWF 2,000 to 8,000 and the average paid per trip is RWF 2,795.

Table A5.9: Taxes and royalties paid to the selling District by the distributor

Type of Royalties	Amount paid for transported charcoal (RWF)		
	Per trip	***Per month*** *(8 trips) for 70,400 kg*	***Per ton***
Unloading	1,580	12,640	180
Cleaning	2,795	22,360	318
Total		**35,000**	**497**

Source: Primary data collected from charcoal Distributors/transporters

– ***Direct cost for charcoal distribution***

The analysis of charcoal distribution costs other than taxes and royalties is based on the following assumptions:

Assumptions based on the data collected from the field:

1. The charcoal distributor is the truck's owner
2. The truck used for transportation has a capacity of 10 tons and charcoal is packed in bags
3. The truck makes 8 trips of 2 days each per month on average; this means 16 days a month. It is assumed that the truck is then available for other activities thereafter;
4. The estimated costs are for 8 one way trips per month because the truck comes from the selling place loaded with other goods for the towns close to the charcoal production sites.
5. The truck transports 200 bags of 44 kg per trip and 1,600 bags per month, which correspond to 70,400 kg.
6. The time used by the truck for charcoal transportation is estimated at 30% of total truck working time given the fact that it makes one way trips for 8 times per month.
7. The truck depreciation is calculated over a 5 years period based on the prices of used truck (Mitsubishi FUSO); RWF 22,000,000.
8. Truck maintenance includes the cost of oil, wheels and other services

Loading and unloading activities are being paid per bag both at the production and at the selling place. The amount paid either for loading or unloading is RWF 100 per bag. The amount paid for loading and unloading is estimated at RWF 320,000 and RWF 4,545 per ton.

The charcoal distributor also pays commissions to middlemen who support in the purchasing and selling of charcoal. There are two main payment systems for middlemen; flat commissions negotiated between distributor and middleman.

The commissions paid to the middlemen are estimated based on the flat commissions paid by the distributor and it is valued to an average of RWF 9,400 per trip and RWF 75,200 per month. The estimated value of commissions paid by distributor to middleman per ton is equal to RWF 1,068.

Table A5.10: Direct cost for charcoal distribution

Type cost	Amount paid for transported charcoal (RWF)	
	Per month *(8 trips) for 70,400 kg*	***Per ton***
Fuel	722,000	10,256
Car maintenance, insurance and depreciation	197,400	2,804
Salary for driver	63,000	895
Loading and unloading	320,000	4,545
Commissions for Middlemen	75,200	1,068
Other expenses(restaurant, accommodation, penalties...)	32,400	460
Total	**1,410,000**	**20,028**

Source: Primary data collected from charcoal Distributors/transporters

– ***Profit from charcoal distribution***

Table A5.11 summarizes the costs and profit obtained from charcoal distribution. The amount of sales is RWF 9,760,000 per month and RWF 138,636 per ton of charcoal while the total cost of distributing 1600 bags (*70,400* kg) or one ton of charcoal is respectively RWF 2,199,400 or RWF 20,028. The level of profit received by the charcoal distributor per month is RWF 1,117,800 or15,878 per ton.

Table A5.11: Cost and Profit from charcoal distribution

Quantity of charcoal distributed	**Value of charcoal at the production place**	**Distribution costs (RWF)**				**Sales (RWF)**	**Profit (RWF)**
		Taxes and royalties paid to (RWF)		**Direct Costs (RWF)**	***Total* (RWF)**		
		Production District	*Selling District*				
1,600 bags (*70,400* kg)	6,720,000	477,200	35,000	1,410,000	8,642,200	9,760,000	1,117,800
One ton	95,455	6,778	497	20,028	122,758	138,636	15,878

Source: Primary data collected from charcoal Distributors/transporters

d) Cost and profit for charcoal selling

The cost and profit analysis of charcoal selling has been done separately for Kigali and other towns.

The costs paid by the dealer for charcoal selling engross the amount paid to distributor for charcoal, the patent costs, District taxes, cleaning and guarding fees. Dealers located on one site (market or open site) share all the costs related to charcoal and fuelwood selling.

– *Costs and sales of charcoal*

A dealer respectively sells an average of 142 bags of 44 kg per month in Kigali city or 121 bags per month in other towns. The purchasing price paid by the dealer to distributor is estimated at RWF 6,122 (6,073 - 6,171) per bag in Kigali city and RWF 6,635 (5965 - 7,305) per bag in other towns. The total value of purchased charcoal is therefore valued to RWF 866,200 in Kigali and RWF 798,600 in other urban areas per month. This corresponds to RWF 138,636 and RWF 150,000 per ton.

The same quantity of charcoal is respectively sold at RWF 7,200 and 7,700 in Kigali and other urban areas respectively. The total market value of charcoal sold by dealer per month both in Kigali city and other towns is respectively estimated at RWF 1,022,400 and RWF 931,700. Considering an average bag weight of 44 kg, a ton of charcoal at the market is valued RWF 163,636 and 175,000 in Kigali and other tows respectively.

– *Taxes and royalties paid for selling charcoal*

The total amount of taxes and royalties paid by a dealer to the selling District is estimated at RWF 6,600 per month in Kigali city and RWF 5,200 per month in other towns. These taxes and royalties include monthly district taxes, patent fees paid once a year, security and cleaning fees. Dealers in other towns usually do not pay patent fees and pay less taxes than those of Kigali City. Table A5.12 summarizes the total taxes and royalties paid per month for charcoal selling and estimates the taxes paid for each ton of charcoal sold.

Table A5.12: Taxes and royalties paid for selling charcoal

Type of type of tax and royalties	Amount paid			
	Kigali		***Other Towns***	
	For 142 bags (average amount sold per month)	*Per ton*	*For 121 bags (average amount sold per month)*	*Per ton*
Monthly District taxes	3,500	560	3,500	657
Patent fee per month	1,200	192	-	-
District Security fees	900	144	900	169
Cleaning fees	1,000	160	800	150
Total	**6,600**	**1,056**	**5,200**	**977**

Source: Estimation done based on primary data collected from charcoal dealers

– *Direct cost of selling charcoal*

The direct costs paid for selling charcoal include the amount paid to manpower to help packing or unpacking bags once or twice a week, rent, guards and other expenses. Table A5.13 illustrates the direct costs paid by dealers both in Kigali and other towns. Dealers in Kigali city spend about RWF 2,177 per ton as direct expenses, while in other towns these direct costs amount to RWF 1,127, about a half what is paid by dealers in Kigali. This is mainly due to the low amount of taxes paid and the cheaper manpower and rents outside Kigali.

Table A5.13: Direct costs for charcoal selling

Type of cost	Amount			
	Kigali		***Other Towns***	
	For 142 bags of 44 kg (average amount sold in one month)	*Per ton*	*For 121 bags of 44 kg (average amount sold in one month)*	*Per ton*
Manpower	2,300	368	1,700	319
Rent	7,000	1,120	1,800	338
Guards	2,300	368	1,000	188
Other expenses	2,000	320	1,500	282
Total	**13,600**	**2,177**	**6,000**	**1,127**

Source: Estimation done based on primary data collected from charcoal dealers

– *Profit earned from charcoal selling*

The total profit earned by dealer per month in Kigali is estimated at RWF 136,000 in Kigali city and 121,900 in other towns. The profit per ton of charcoal sold in other town is higher than in Kigali city: RWF 22,896 against RWF 21,767 in Kigali city.

Table A5.14: Profit earned by the dealer from charcoal selling

Quantity of charcoal sold	***Costs (RWF)***				***Sales (RWF)***	***Profit (RWF)***
	Charcoal	*Taxes and royalties*	*Direct costs*	*Total*		
Kigali						
142 bags (average amount sold per month)	866,200	6,600	13,600	886,400	1,022,400	136,000
1 ton	138,636	1,056	2,177	141,869	163,636	21,767
Other towns						
121 bags (average amount sold per month	798,600	5,200	6,000	809,800	931,700	121,900
1 ton	150,000	977	1,127	152,104	175,000	22,896

Source: Primary data collected from charcoal Dealers

The summary of costs and profits of the charcoal value chain is presented and discussed in the main text of the report. See Section 3.2.1 "Overview of costs and profit for charcoal value chain" and Table 40 for a synthetic overview.

Economic magnitude of fuelwood and charcoal trading

Table A5.15 provides a District-wise estimation of the value of the charcoal market of Rwanda in 2009 and in 2020 according to BAU and AME scenarios, applying current market prices applied in Kigali and in other urban areas.

Table A5.15 : Market value of charcoal trade in 2009 and in 2020 according to BAU and AME scenarios (applying current charcoal retail practiced in Kigali and in other urban areas).

	Charcoal trade 2009			Charcoal trade 2020 - BAU			Charcoal trade 2020 - AME		
District (2006)	**Rural**	**Urban**	**Total**	**Rural**	**Urban**	**Total**	**Rural**	**Urban**	**Total**
		Million RWF			**Million RWF**			**Million RWF**	
NYARUGENGE	258	6,695	**6,953**	183	8,500	**8,683**	169	6,926	**7,095**
GASABO	1,357	8,686	**10,044**	1,807	13,922	**15,728**	1,666	11,344	**13,010**
KICUKIRO	308	6,907	**7,215**	340	10,238	**10,578**	314	8,343	**8,656**
NYANZA	118	542	**660**	218	1,245	**1,463**	201	1,082	**1,283**
GISAGARA	146	127	**274**	278	294	**572**	256	255	**511**
NYARUGURU	136	0	**136**	266	0	**266**	246	0	**246**
HUYE	112	920	**1,032**	167	2,016	**2,183**	154	1,751	**1,906**
NYAMAGABE	135	394	**529**	223	881	**1,104**	206	765	**971**
RUHANGO	121	455	**576**	208	1,028	**1,235**	191	893	**1,084**
MUHANGA	100	1,049	**1,148**	126	2,171	**2,297**	116	1,886	**2,002**
KAMONYI	148	0	**148**	281	0	**281**	259	0	**259**
KARONGI	526	255	**782**	1,054	376	**1,430**	972	327	**1,299**
RUTSIRO	548	0	**548**	1,079	0	**1,079**	995	0	**995**
RUBAVU	538	621	**1,159**	1,182	990	**2,172**	1,090	862	**1,952**
NYABIHU	555	0	**555**	1,090	0	**1,090**	1,005	0	**1,005**
NGORORERO	574	0	**574**	1,109	0	**1,109**	1,022	0	**1,022**
RUSIZI	623	295	**918**	1,237	431	**1,668**	1,140	375	**1,516**
NYAMASHEKE	661	0	**661**	1,279	0	**1,279**	1,179	0	**1,179**
RULINDO	151	0	**151**	277	0	**277**	255	0	**255**
GAKENKE	178	0	**178**	298	0	**298**	275	0	**275**
MUSANZE	176	427	**604**	358	717	**1,075**	330	624	**954**
BURERA	182	0	**182**	315	0	**315**	290	0	**290**
GICUMBI	251	430	**680**	579	785	**1,364**	534	684	**1,218**
RWAMAGANA	193	133	**326**	447	251	**698**	413	218	**631**
NYAGATARE	250	224	**473**	631	442	**1,073**	582	385	**967**
GATSIBO	314	0	**314**	830	0	**830**	765	0	**765**
KAYONZA	214	0	**214**	535	0	**535**	494	0	**494**
KIREHE	214	0	**214**	500	0	**500**	462	0	**462**
NGOMA	201	102	**303**	441	187	**628**	407	163	**570**
BUGESERA	242	108	**350**	571	205	**776**	526	178	**705**
Total Rwanda	**9,530**	**28,369**	**37,900**	**17,910**	**44,678**	**62,588**	**16,513**	**37,063**	**53,577**

Table A5.16 provides a District-wise estimation of the value of the fuelwood market of Rwanda in 2009 and in 2020 according to BAU and AME scenarios. In view of the variety of prices and of the informal character of fuelwood trade, more complex is to assess in monetary terms the economic magnitude of fuelwood. The estimation presented in Table A5.16 was reached by allocating a small price for the non-commercial fuelwood consumed by rural households (i.e. 8 RWF/kg based on the estimated collection time; applied to 80% of the rural HH demand) and applying the commercial price for fuelwood in rural areas (500 RWF/bundle, or 11,667 RWF/stere; applied on the remaining 20% of rural HH demand); applying the commercial price of 6000 RWF per stere (17.1 RWF / kg) for the fuelwood consumed by large consumers (schools, prisons, brick makers, tea factories) and applying the commercial price of 1500RWF/bundle (or 35,000 RWF/stere) to urban households demand.

Table A5.16: Market value of fuelwood trade in 2009 and in 2020 according to BAU and AME scenarios (applying current fuelwood retail prices).

	Fuelwood (fw) trading 2009					Fw trade 2020 - BAU	Fw trade 2020 - AME
District (2006)	Rural HH Non-commercial	Rural HH Commercial	Urban HH Commercial	Other uses	Total	Total	Total
	Million RWF					Million RWF	Million RWF
NYARUGENGE	33	35	1,213	156	**1,437**	**1,166**	**581**
GASABO	175	182	1,574	183	**2,115**	**2,120**	**1,148**
KICUKIRO	40	41	1,252	76	**1,409**	**1,335**	**659**
NYANZA	520	542	875	79	**2,017**	**3,153**	**2,734**
GISAGARA	647	674	206	25	**1,552**	**2,109**	**1,905**
NYARUGURU	600	625	0	107	**1,333**	**1,707**	**1,577**
HUYE	495	515	1,485	211	**2,706**	**4,064**	**3,470**
NYAMAGABE	597	622	635	112	**1,967**	**2,702**	**2,366**
RUHANGO	535	557	735	124	**1,952**	**2,840**	**2,484**
MUHANGA	441	459	1,693	143	**2,737**	**3,970**	**3,364**
KAMONYI	654	681	0	27	**1,363**	**1,716**	**1,577**
KARONGI	617	642	907	102	**2,269**	**2,924**	**2,576**
RUTSIRO	642	669	0	24	**1,334**	**1,632**	**1,498**
RUBAVU	630	656	2,207	177	**3,670**	**5,201**	**4,501**
NYABIHU	650	677	0	44	**1,371**	**1,674**	**1,535**
NGORORERO	672	700	0	64	**1,437**	**1,721**	**1,580**
RUSIZI	730	760	1,047	129	**2,667**	**3,387**	**2,985**
NYAMASHEKE	775	807	0	305	**1,887**	**2,214**	**2,053**
RULINDO	581	605	0	114	**1,301**	**1,515**	**1,386**
GAKENKE	689	718	0	317	**1,724**	**1,818**	**1,684**
MUSANZE	680	709	1,518	212	**3,119**	**4,372**	**3,815**
BURERA	704	733	0	30	**1,467**	**1,615**	**1,475**
GICUMBI	969	1,009	1,526	236	**3,740**	**5,721**	**5,041**
RWAMAGANA	576	600	473	110	**1,759**	**2,546**	**2,243**
NYAGATARE	744	775	794	67	**2,380**	**3,809**	**3,365**
GATSIBO	937	976	0	33	**1,946**	**3,032**	**2,780**
KAYONZA	638	664	0	33	**1,335**	**1,976**	**1,805**
KIREHE	637	664	0	24	**1,325**	**1,826**	**1,679**
NGOMA	598	623	363	56	**1,641**	**2,273**	**2,021**
BUGESERA	723	753	382	69	**1,926**	**2,794**	**2,500**
Total Rwanda	**17,930**	**18,677**	**18,886**	**3,392**	**58,885**	**78,931**	**68,386**

Profile of traders and business models involved in fuelwood and charcoal trading activities

The value chains of charcoal and fuelwood encompass 6 main categories of actors with the organization models of each category differing from each another.

a) Wood producers

Wood producers include private and public (District and Government) producers. Private wood producers are made up by individual households that own plantations and woodlots of small size, plus institutions such as schools, churches, religious organizations, and tea factories.

Charcoal and fuelwood are mainly produced from small woodlots owned by households. Institutions usually produce fuelwood from their own plantation for self-consumption or for reforestation purposes.

b) Charcoal producer

Charcoal producers can be divided into three main categories “Wood owners”, “manpower” and “distributors”.

A woodlot owner is considered as charcoal producer when she/he decides to produce charcoal from own tree plantation. In that case she/he can carbonize wood autonomously or hire someone to help.

Charcoal distributors or businessmen are considered as charcoal producers when they buy tree plantations from woodlot owners and hire manpower to carbonize them.

The charcoal producer-manpower is made up by people who have expertise in charcoal production but have neither the woodlot nor the investment power to buy trees to carbonize. They work for woodlot owners or businessmen/distributors who want to carbonize bought or own trees.

c) Distributor

The fuelwood and charcoal distributor category is also made up by three sub-categories; vehicle owners, vehicle renters and middlemen or commissionaires.

The fuelwood and charcoal distributor can be the car owner who buys fuelwood and charcoal from the production place, and transports/distributes it to the selling place directly or using a hired driver.

The distributor could also rent a car and do her/himself all the activities related to buying and distributing the charcoal.

The third category is made up by middlemen who work for distributors either for buying or selling. Their contribution in buying and selling activities varies to a considerable extent and their payment depends on the level of contribution.

d) Charcoal and fuelwood dealers/retailer

Charcoal and fuelwood dealers/retailer are in charge of selling charcoal to the final consumer and can be found in the markets, shops or on open-air storage areas. They may be working in cooperative or individually.

e) Consumers

Consumers of charcoal and fuelwood include households, the commercial sector, public and industrial sectors.

f) Others

Other actors include the local and central government, financial service providers and other service providers.

The central government contributes to fuelwood and charcoal production by establishing the policy regarding the management of the production while local authorities implement that policy. As a compensation, the local government collects taxes and royalties.

The financial service providers intervene in saving the income generated by the whole value chain and provide loans especially to wood producers.

Other actors of the fuelwood and charcoal value chain are tools and equipment providers, fuel suppliers, restaurant owners, loading and unloading manpower, and other people who supply services to support one of the activities supporting the fuelwood and charcoal value chain.

Administrative requirement and taxation for harvesting, charcoal production and transportation

a) Administrative requirements and taxation for harvesting and charcoal production

– *Government and District Plantations*

The permit for harvesting government tree plantations is given by the National Forest Agency. The permit is normally provided to the one who wins the tender for harvesting after paying the cost of standing trees to the national forest fund account. Sometimes the harvesting of particular plantations requires permission from the Ministry in charge of forests.

Harvesting the District tree plantations is authorized by the mayor to the one who wins the tender for harvesting. The District Forest Officer has first to confirm in writing that the tree plantation is mature for harvesting.

In both government and district plantation harvesting, the District Forest Officer oversees the process of harvesting and gives advice to the one who has won the tender for harvesting.

– *Private Plantations*

According to ministerial instructions on tree plantation management the following applies:

1. Harvesting plantations with a surface area of less than 0.5 hectare does not require a tree-cutting permit. However, it is not allowed to harvest plantations, which are closer than 20 m to each other within a period of less than 3 years.
2. For plantations between 0.5 and 2 hectares, the plantation owner has to inform the District forest officer so that he may get advices on how to harvest it.
3. When the forested area is equal to or greater than 2 hectares, harvesting requires a tree cutting permit. The tree-cutting permit is delivered after payment of 1% of the value of the plantation to the National Forest Fund.
4. In case of not-regenerating trees the harvest is subjected to a written commitment that the owner will plant trees on the same land during the following tree plantation season.
5. Someone who illegally harvests a plantation (without a tree cutting permit when required) pays double the amount she/he would have to pay for obtaining the tree cutting permit to the national forest fund.

In practice, such instructions are applied/ interpreted in different ways from one District to another. The District, - through its task force which consists of 12 participants: 1.DFO, 2.Army representative, 3.Policy representative, 4.Vice mayor for economic affairs, 5.Youth representative, 6.Women representative, 7.Representative of NGOs that work in forestry or related sectors, 8.Environment officer, 9. Director of lands, and three other participants selected by the district advisory council - sets up its own requirements and costs to deliver the tree harvesting permit. The availability of wood stock, the level of exploitation, time, etc. guide this task force in setting up specific requirements. Table A5.17 shows requirements that apply in all Districts. More specific District-wise requirements include the following:

1. In most Districts, the harvesting of tree plantations, regardless of their size is subjected to permit issuance, that is issued free of charge for plantations of less than 0.5 ha. A maximum of one tree cutting permit is delivered per month and per cell. A maximum of 12 tree plantation owners could theoretically get the permit for harvesting their trees per year per any given cell[31].
2. The delivery of tree cutting permits is subjected not only to the payment of 1% of the value of the plantation to the national forest fund but also to other costs such as:
    - The costs of tree cutting permit issuance itself which varies from RWF 1,200 to 5,000 in less producing Districts and from RWF 10,000 to 15,000 in Districts with a higher production.
    - The required contribution to development activities, requested to all businessmen engaging on any kind of economic enterprise.
3. The tree cutting permit lasts only one month and it is delivered for a single plot.
4. Some Districts require everyone who wants to get the tree cutting permit to plant as many trees as the ones to be harvested, even if the utilised trees will regenerate in a coppice system.
5. Districts may ban completely tree cutting for a given period at the District level or in some Sectors for different reasons. This ban could be justified by two reasons: the overexploitation in a given area and fire prevention during the dry season.

Table A5.17: Summary of the administrative wood exploitation requirements in all districts

Administrative requirements	
For plantations less than 0.5 ha	**For plantations exceeding 1 ha**
• Approval of village Authorities that witnesses and confirms that the tree plantation is somebody's property. • Approval of the cells coordinator. • Visit of sector agronomist who gives advices and delivers tree-cutting permit.	• Approval of the village Authorities that witnesses and confirms that the tree plantation is somebody's property. • The Approval of the cell coordinator; • Visit of sector agronomist who gives a go ahead to the District for authorizing tree-cutting permit. • Visit of District Environment officer who then delivers tree-cutting permit. • Payment of 1% of the value of the forest or a fixed amount which goes to the national forest fund • Payment of cost of permit, taxes and other royalties fixed by the District

a) Administrative requirements and taxation for charcoal transportation permit

The transportation of charcoal and other woody products is subjected to the issuance of a transportation permit. The ministerial instructions stipulate that the permit may last no more than 3 months and the transporter has to pay for the service of its delivery but it does not fix the amount to be paid. This allows Districts to fix the price of and the time needed to obtain a charcoal transportation permit. The cost of a transportation permit varies from RWF 6,000 to 50,000.

Apart from the transportation permit cost, the distributor is required to pay a tax per bag which varies

[31] This can be a serious constraint in some areas, considering that more than 1000 cells (50% of all cells) have more than 100 ha of plantations and more than 200 cells have plantation areas between 300 and over 1000 ha.

from RWF 100 to 200, the loading tax and a contribution to social development activities.

According to the instructions of the Ministry in charge of forests, a charcoal distributor who is caught transporting charcoal without fulfilling all administrative requirements is charged 5 times the total amount of taxes and royalties she/he had to pay to the District. In addition, she/he has to be charged for forest offences.

b) Threats regarding the taxation strategy

The rigidity of the process, the cost of tree cutting permits and the generic state of poverty, induce wood owners to adopt a negative approach on the management of resources and on fuelwood and charcoal production systems:

- Wood owners opt for clandestine tree cutting and charcoal production. Clandestine production affects the quality and quantity of the charcoal produced, and induces irrational harvesting and loss of taxes:
    - Those who do not have a permit, tend to cut and char the wood very rapidly so that they may not be caught by local authorities. This affects both quality and quantity of charcoal, because the wood that is not dry enough can result over-charred or under-charred.
    - Tax evasion in the production districts
    - The cutting of immature trees/stands because producers are unsure that they will get the opportunity in the future to cut trees without being caught.
- Even those who hold a permit cannot always apply good practices and/or improved techniques because the permit only lasts for one month. Good charcoal making requires time and preparation, especially adequately drying of cut wood in order to assure good yield and high charcoal quality.
- Land owners are discouraged to plant more trees because it is not easy to harvest them or to replace the plantation should they opt for other more profitable activities.

c) Opportunities for the improvement of the taxation strategy

An improvement of taxation strategy may be reached through a rationalisation of the forest law and issuance of more specific instructions regarding law implementation of this law. sensitization on the law and instructions on how best regulate forests and sustainable forest management should be done among tree plantations owners, farmers and local authorities.

- **Improvement of the forest law and government instructions regulating forests**

The law and ministerial instructions regarding forests could be improved in order to assure sustainable management. Below are examples of articles that should be reviewed or introduced;

- **Article 67** of the forest law stipulates that in their appreciation of tree cutting, the authorities take into consideration the necessity of soil conservation, the wild fauna and flora, regulation of the hydric system as well as agriculture and husbandry without providing detailed criteria for delivering the tree cutting permit. This provides room for local authorities to withheld tree cutting permits without further justification.

- **Article 9** of the ministerial instructions indicates that harvesting plantations of less than 0.5 ha does not require a prior permit. However in its second part it prohibits anyone to harvest a plantation of the same size located within 20 meters of a harvested plantation before the end of 3 years. This means that the woodlot owners with plantations separated by a distance inferior or equal to 20 meter have to wait 3 years times the number of their plots. This increases the illegal production of wood for different purposes and charcoal. A possible way out would be to allow everyone to cut her/his trees according to the community forest management plan approved by all community members and monitored by a committee made up by community members.

- According to **article 11** of the ministerial instructions, replacement of a tree plantation by other activities is not allowed and when it happens it is subjected to permission of the Minister in charge of forest. This discourages landowners to plant trees because it will be difficult for them to replace trees by other farming activities. To encourage people to plant more trees this measure should be smoothed by limiting the number of years after which the woodlot owner could replace it with other crops.

- The administrative entities defined in the Forest Law as responsible for permit issuance should be harmonized with the current territorial administration structure in order to simplify and streamline procedures and make them more easily accessible to woodlot owners. Specifically, it is recommended that tree cutting permits be delivered at the Sector level rather than at the District.

- The Forest Law and wood products taxation system should clearly fix the amount of taxes to be paid and all administrative requirements in order to harmonize them at national level and thus reduce the chance for irrational or different local interpretations. The amount to be paid should not only be proportional to the quantity cut, produced and/or transported but also favor implementation of efficient production techniques. Higher charges should be applied to those who use inefficient techniques or will replace tree plantations with other activities.
- In order to simplify administrative procedures, reduce costs and increase income of central and local governments, it seems appropriate to propose establishment of a single tax for tree cutting and/or charcoal making and another one for the transportation of wood products, in substitution of the current sets of different taxies and levies.

- **Streamlining implementation of instructions regulating forests**

For a more rational implementation of the Forest Law and related instructions regulating forests the following activities are recommended:

- As recommended by article 62, woodlots owners of plantations of 2 ha or above should be supported to elaborate a forest management plan. The agency should support woodlot owners and communities to get their own forest management plan and establish forest management committees.
- Local authorities and tree plantation owners should be trained and sensitized on the law and ministerial instructions regulating forestry and sustainable management of forests.

Socio-economic dimensions of fuelwood and charcoal production schemes

Benefits from wood production can be classified into 3 categories.

- **Main source of cooking energy**

As evidenced by several surveys (latest EICV 3) and discussed in Part 1 of the present report, more than 86% of households use fuelwood as their main cooking energy and 11% of the total population (but 55% of urban) use charcoal. This makes charcoal and fuelwood the main cooking energy for Rwandan households.

- **Environment protection**

Most of the time trees are planted on infertile / waste lands or on hillsides with a steep slope of more than 40% where other crops cannot grow. Tree plantation in such areas protects the soil against erosion and increases value of land, which is not otherwise productive.

- **Income generation for households and Districts**

According to ECIVIII agriculture is the backbone of Rwanda's economy as the majority of households in Rwanda are engaged in some sort of crop or livestock production activity[32] particularly in rural areas. In Districts with large proportions of steep and unfertile lands, production of fuelwood and charcoal constitutes the main source of income for households. Households get income from fuelwood and charcoal selling or provision of services related to production of fuelwood or charcoal. Districts in turn receive conspicuous proportions of taxes and royalties on harvesting trees and transportation of woody products.

- **Access to loan for development activities and investments**

Tree plantations constitute a main asset for the rural population, which may be used as a guarantee acceptable by financial institutions. Even if it takes a long time for tree plantations to be harvested, plantation owners may nevertheless request a loan and use the plantation as a collateral. This loan helps wood owners to diversify their sources of income starting a business, acquiring equipments or cattle, improving crop production, etc.

Charcoal producers are not yet keen to use loans from banks in fear of losing money. Their savings are made occasionally, a fact that would not permit them to get loans easily. Those who were looking for loan stated that banks are taking too long to deliver it as they were in immediate need for cash.

Employment generated by the charcoal chain

A summary of data on employment generation by the charcoal value chain is presented and discussed in the main text of the report. See Section 3.2.2 "Overview of employment generation by the charcoal value chain" and Table 41 for a synthetic overview.

[32] EICV III: National Institute of Statistic, 2010 p.98

ANNEX 6: NAMES AND DESCRIPTION OF MAIN MAPS

Raster maps are at 50 m resolution, unless otherwise specified.

Module/filename	Type	Description
Cartographic base		
SECTEURS_2002_m	v	Map of sectors 2002 version
SECTEURS_2006_m	v	Map of sectors 2006 version
District06	v	Map of Districts 2006 version
dist06	v	Map of Districts 2006 version
Province_2006_m	v	Map of Province 2006 version
Rwanda_boundary_m	v	Rwanda boundaries as per District 2006 version
sect02	r	Raster map of sectors 2002 version
sect_06	r	Raster map of sectors 2006 version
dist06	r	Districts 06 with value = to administrative code
prov06		Province 06 with value = to administrative code
rwa_msk1	r	Mask of Rwanda administrative area (value=1)
rwa_msk0	r	Mask of Rwanda administrative area (value=0)
Accessibility maps		
		Physical accessibility
slp50_cont25		
slp50_rnra3		
sl50patch_res		
slp50		Final 50m slope map covering whole Rwanda
trade_arc60		raster of trade centres (val 1) from "trade_cent_arc60.shp"
main_rd		raster of main roads (val 1) from "nat_dist_tarred_roads.shp" derived from "roads09_arc60.shp" by selecting only national, district roads and tarred Other roads
urban_area3		Raster of urban areas
distance0		Starting feature of cost-distance analysis created by merging of trade_arc60 main_rd and urban_area3
cd_main_rd		cost-distance based on distance0 (main roads only) and slp50 model: cost distance main roads
		Legal accessibility
Rwa_I_IV_p.shp	v	2009 delineation of IUCN-WCMC categories
Iucn_noacc0	r	Map of no access for IUCN-WCMC protected areas clipped on cty boundaries
Marshland_categories.shp	v	Marshland map with associated protection categories
marsh_noacc0	r	Map of no access for total protected marshlands
leg_acc		Map of non accessible areas due to legal constraints (0= no access; 1= full access) = merge (iucn_noacc0, marsh_noacc0, rwa_cty)
		Potential new plantation areas above pre-defined slope
slp55msk		mask of slp50 over 55% slope
slp50msk		mask of slp50 over 50% slope
slp60msk		mask of slp50 over 60% slop
nofor_msk		Non forest mask (value=1) (including protected areas)
ac_nofor_msk		Legally accessible Non forest mask (value=1; protected non-forest=0)

		= "%nofor_msk%" * "%leg_acc%"
ac_nofor55slp		Area potentially suitable for plantation (land area with slope above 55%, not covered by natural vegetation and not already planted. Not protected =1; protected=0). Resolution 50 m (0.25ha cell) = "%ac_nofor_msk%" * "%slp55msk_1%"
slp10_a60		Slope map at 10m resolution based on DTM 10m (RNRA)
slp10_55msk		Mask of areas with slope >= 55% (10m resolution)
ac_nof55slp10		Accessible non-forest area with slope >= 55% at 10m resolution
Demand Module		
		Population 2002 distribution
10HH_rwa2002	v	original 10 household data set (Nyumba Kumi)
HH10_by_Sector_Rural_2	v	10 household points limited to rural areas and integrated/reviewed for the sectors without points
hh10_rur4	r	Raster of rural areas (after removal of hh10 points covered by urban areas)
urban_area3		Raster of urban areas adjusted for Musanze town = merge(musanze_1, urban_area2)
rur2_2002		Rural population 2002 assigned to rural area pixels (pop * 100) = merge(hh10_rur4 * reclass(sect02, recl_sec02_rur_x_pix.txt), rwa_msk0)
urb2_2002		Urban population 2002 assigned to urban area pixels (pop * 100) = merge(urban_area3 * reclass(sect02, recl_sec02_urb_x_pix.txt), rwa_msk0)
rur2009		Rural population 2009 assigned to rural area pixels (pop * 100) = rur2_2002 * (reclass(dist06_cod, recl_dist06_mul_rur02_rur09.txt)) / 1000
urb2009		Urban population 2009 assigned to rural area pixels (pop * 100) = urb2_2002 * (reclass(dist06_cod, recl_dist06_mul_urb02_urb09.txt)) / 1000
pop2009		Total population 2009 (pop * 100) = merge(urb2009, rur2009)
rur2020		Rural population 2020 assigned to rural area pixels (pop * 100) = rur2002_0 * (reclass(dist06_cod, recl_dist06_mul_rur02_rur20.txt)) / 1000
urb2020		Urban population 2020 assigned to rural area pixels (pop * 100) = urb2002 * (reclass(dist06_cod, recl_dist06_mul_urb02_urb20.txt)) / 1000
pop2020		Total population 2020 (pop * 100) = merge(urb2020, rur2020)
pop2009_f30		Smoothed 2009 population map = focalmean(pop2009, circle, 20 and 10) * rwa_msk1
pop2020_f30		Smoothed 2020 population map = focalmean(pop2020, circle, 20 and 10) * rwa_msk1
		HOUSEHOLD SECTOR
		HH consumption for cooking and heating – based on updated saturation and consumption values
		2009 HH consumption
hhdem09_rur		= int((50 + rur2009 * reclass(dist06_cod, recl_dist06_pc_rur_cons09_odkg.txt)) / 100)
hhdem09_urb		= int((50 + urb2009 * reclass(dist06_cod, recl_dist06_pc_urb_cons09_odkg.txt)) / 100)
hhdem09_f20		= focalmean(hhdem09_rur + hhdem09_urb, circle, 20) * rwa_msk1
hhdem09_f30		= focalmean(hhdem09_f20, circle, 10) * rwa_msk1
		2020 HH consumption – BAU scenario
hhdem20_rur		= int((50 + rur2020 * reclass(dist06_cod, recl_dist06_pc_rur_cons20_odkg.txt)) /

	100)
hhdem20_urb	= int((50 + urb2020 * reclass(dist06_cod, recl_dist06_pc_urb_cons20_odkg.txt)) / 100)
	2020 HH consumption – AME scenario
hh20_rur_ame	Rural Household sector consumption 2020 - AME scenario (odkg / pixel) = int((50 + rur2020 * reclass(dist06_cod, recl_dist06_pc_rur_cons20_odkg_ame.txt)) / 100)
hh20_urb_ame	Urban Household sector consumption 2020 - AME scenario (odkg / pixel) = int((50 + urb2020 * reclass(dist06_cod, recl_dist06_pc_urb_cons20_odkg_ame.txt)) / 100)
	COMMERCIAL SECTOR
	Consumption by Commercial sector – based on updated urban HH demand
	2009
comdem09	Commercial sector consumption 2009 (odkg / pixel) = int(0.5 + hhdem09_urb / 10)
	2020 Commercial consumption – BAU scenario
comdem20	Commercial sector consumption 2020 - BAU scenario (odkg / pixel) = int(0.5 + hhdem20_urb / 10)
	2020 Commercial consumption – AME scenario
comdem20_ame	Commercial sector consumption 2020 - AME scenario (odkg / pixel) = int(0.5 + hh20_urb_ame / 10)
	Charcoal consumption in HH and Commercial sectors
	2009
ch_rur09kg	= int((5000 + rur2009 * reclass(dist06_cod, recl_dist06_pc_rur_CH_10g09.txt)) / 10000)
ch_urb09kg	= int((5000 + urb2009 * reclass(dist06_cod, recl_dist06_pc_urb_CH_10g09.txt)) / 10000)
ch09kg_f20	= focalmean(ch_rur09kg + ch_urb09kg, circle, 20) * rwa_msk1
ch09kg_f30	= focalmean(ch09kg_f20, circle, 10) * rwa_msk1
	2020 Charcoal consumption – BAU scenario
ch_rur20kg	= int((5000 + rur2020 * reclass(dist06_cod, recl_dist06_pc_rur_CH_10g20.txt)) / 10000)
ch_urb20kg	= int((5000 + urb2020 * reclass(dist06_cod, recl_dist06_pc_urb_CH_10g20.txt)) / 10000)
	2020 Charcoal consumption – AME scenario
ch_rur20amepc	= reclass(dist06_cod, recl_dist06_pc_rur_CH_10g20_ame.txt)
ch_rur20_ame	= Int(("%ch_rur20ame00%" * "rur2020")/ 10000 + 0.5)
ch_urb20amepc	= reclass(dist06_cod, recl_dist06_pc_urb_CH_10g20_ame.txt)
ch_urb20_ame	= Int(("%ch_urb20ame00%" * "urb2020")/ 10000 + 0.5)

	HH consumption for construction wood
constr09_kg	Construction wood consumption 2009 (odkg / pixel) = int((50 + rur2009 * reclass(dist06_cod, recl_dist06_pc_rur_constru09_odkg.txt) + urb2009 * reclass(dist06_cod, recl_dist06_pc_urb_constru09_odkg.txt)) / 100)
constr09_f30	Smoothed map of construction wood consumption 2009 = focalmean(constr09_f20, circle, 10) * rwa_msk1
constr20_kg	Construction wood consumption 2020 (odkg / pixel) = int((50 + rur2020 * reclass(dist06_cod, recl_dist06_pc_rur_constru20_odkg.txt) + urb2020 * reclass(dist06_cod, recl_dist06_pc_urb_constru20_odkg.txt)) / 100)
constr20_f30	Smoothed map of construction wood consumption 2020 = focalmean(constr20_f20, circle, 10) * rwa_msk1
	PUBLIC SECTOR
	Consumption by Secondary schools
	See file Secondary_schools_students_consumption_2002_2009_2020_REV02.xls
Secs_Schools_RNRA2011_arc60_utm35.shp	Map of secondary schools
secschool_09	Raster map of secondary schools in 2009
sec_stud02	Secondary students in 2002
secstu09_100	Secondary students in 2009
secstu20_100	Secondary students in 2020
ssch3kg09	Mod_sch_3_09 = MERGE(secschool_09 * reclass(prov06, recl3_prov06_ssc_cons_odkg_09.txt), rwa_msk0)
ssch3kg20	Mod_sch_3_20 = secschool_09 * reclass(prov06, recl3_prov06_ssc_cons_odkg_20.txt)
ssch3kg20ame	= int(0.5 + ssch3_kg_20 * 0.5)
	Consumption by prisons
prisons_avg_06_08.shp	
pris_odkg0	raster based on points' attributes
pris20_bau	= int(0.5 + pris_odkg0 * 0.75
pris20_ame	= int(0.5 + pris20_bau * 0.5)
	INDUSTRIAL SECTOR
	Consumption by tea factories
Tea_Factories_avg_07_08.shp	This map has a wrong xtent ! Northern and southern points are outside!
tea09_kg0	Fuelwood consumption (avg. 07-08) in od kg
	Consumption by brickmakers
brick_cons09	Tentative mapping of wood consumption for bricks production Mod_brick_demand: District-level consumption distributed using rural pop 09 as spatial proxy.
	Total demand
dem09	Mod_dem09
dem09_f30	Mod_focal_dem09
dem20	Mod_dem20
dem20_f30	Mod_focal_dem09

dem20_ame	Mod_dem20_ame
dem20ame_f30	Mod_focal_dem09_ame
	Modulation of Rural consumption of "conventional" woodfuels based on local wood availability (excluding marginal fuelwood used in rural areas)
	Demand 2009
avmai_b_4km	= focalmean(avmai_bau, circle, 40) 2 times
avmai_m_4km	= focalmean(avmai_man, circle, 40) 2 times
dem09_4km	= focalmean(dem09, circle, 40) 2 times
pcful_b09_4k	Percent fulfilled within a 4km context - Demand 2009 & Low productivity = avmai_b_4km / dem09_4km * 100
pcful_m09_4k	Percent fulfilled within a 4km context - Demand 2009 & High productivity = avmai_m_4km / dem09_4km * 100
pcful_x09_4k	Percent fulfilled within a 4km context - Demand 2009 & Medium productivity Average of the two low and high productivity variants
dem_b_f70c	Adjustment factor reducing the consumption of "conventional" fuelwood in rural areas on account of scarce resources (max reduction to 70% of demand) - Low productivity variant. = model "from percent fulfilled b to demand factor 70"
dem_m_f70c	Adjustment factor reducing the consumption of "conventional" fuelwood in rural areas on account of scarce resources (max reduction to 70% of demand) - High productivity variant. = model "from percent fulfilled m to demand factor 70"
dem09_adj_b70	**Demand 2009 revised (excluding marginal fuelwood used in rural areas) - Low productivity variant.** = ("%dem09%" * "%dem_b_f70c%") / 100
dem09_adj_m70	**Demand 2009 revised (excluding marginal fuelwood used in rural areas)- High productivity variant.** = ("%dem09%" * "%dem_m_f70c%") / 100
dem09_adj_x70	**Demand 2009 revised (excluding marginal fuelwood used in rural areas)- Medium productivity variant.** ("%dem09_adj_b70%" + "%dem09_adj_m70%") / 2
	Demand 2020
	Adjusted Demand 2020 (excluding marginal fuelwood used in rural areas) - BAU demand scenario, Stable 2009 plantations and Low productivity
dem20_4km	= focalmean(dem20, circle, 40) 2 times
pcful_b20_4k	Percent fulfilled within a 4km context - Demand 2020 BAU & Low productivity = avmai_b_4km / dem20_4km * 100
dem20b_f70c	Adjustment factor reducing the consumption of "conventional" fuelwood in rural areas on account of scarce resources (max reduction to 70% of demand) - 2020 BAU demand & Low productivity variant. = model "from percent fulfilled b to 2020demand factor 70"
dem20_adjbb70	**Demand 2020 revised - BAU demand 2020 & Low productivity variant.** = ("%dem20%" * "%dem20b_f70c%") / 100
	Adjusted Demand 2020 (excluding marginal fuelwood used in rural areas) - BAU demand scenario, Stable 2009 plantations and Medium productivity
avmai_x_4km	= ("avmai_b_4km" + "avmai_m_4km") / 2
pcful20x_b4k	Percent fulfilled within a 4km context - Demand 2020 BAU &Medium productivity = avmai_x_4km / dem20_4km * 100
dem20x_bf70c	Adjustment factor reducing the consumption of "conventional" fuelwood in rural

	areas on account of scarce resources (max reduction to 70% of demand) - 2020 BAU demand & Medium productivity variant. = model "from percent fulfilled to 2020 demand BAU_Medium factor 70"
dem20adjx_b70	**Demand 2020 revised - BAU demand 2020 & Medium productivity variant.** = ("%dem20%" * "%dem20x_bf70c%") / 100
	Adjusted Demand 2020 (excluding marginal fuelwood used in rural areas) - BAU demand scenario, Stable 2009 plantations and High productivity
avmai_m_4km	To be recreated = use Model **focalmean 2 rounds avmai_m_4km**
pcful20m_b4k	Percent fulfilled within a 4km context - Demand 2020 BAU & High productivity = avmai_m_4km / dem20_4km * 100
dem20m_bf70c	Adjustment factor reducing the consumption of "conventional" fuelwood in rural areas on account of scarce resources (max reduction to 70% of demand) - 2020 BAU demand & Medium productivity variant. = model "from percent fulfilled to 2020 demand BAU_High factor 70"
dem20adjm_b70	**Demand 2020 revised - BAU demand 2020 & High productivity variant.** = ("%dem20%" * "%dem20m_bf70c%") / 100
	Adjusted Demand 2020 (excluding marginal fuelwood used in rural areas) - AME demand scenario, Stable 2009 plantations and Low productivity
avmai_b_4km	= use Model **focalmean 2 rounds avmai_b_4km**
pcful20b_am4k	Percent fulfilled within a 4km context - Demand 2020 BAU &Medium productivity = avmai_b_4km / dem20ame_4km * 100
dem20b_amf70c	Adjustment factor reducing the consumption of "conventional" fuelwood in rural areas on account of scarce resources (max reduction to 70% of demand) - 2020 AME demand & Medium productivity variant. = model "from percent fulfilled to 2020 demand AME_Low factor 70"
dem20adjbam70	**Demand 2020 revised - AME demand 2020 & Medium productivity variant.** = ("%dem20_ame%" * "%dem20b_amf70c%") / 100
	Adjusted Demand 2020 (excluding marginal fuelwood used in rural areas) - AME demand scenario, Stable 2009 plantations and Medium productivity
avmai_x_4km	= average of **avmai_b_4km and avmai_m_4km**
pcful20x_am4k	Percent fulfilled within a 4km context - Demand 2020 BAU &Medium productivity = avmai_x_4km / dem20ame_4km * 100
dem20x_amf70c	Adjustment factor reducing the consumption of "conventional" fuelwood in rural areas on account of scarce resources (max reduction to 70% of demand) - 2020 AME demand & Medium productivity variant. = model "from percent fulfilled to 2020 demand AME_Medium factor 70"
dem20adjxam70	**Demand 2020 revised - AME demand 2020 & Medium productivity variant.** = ("%dem20_ame%" * "%dem20x_amf70c%") / 100
	Adjusted Demand 2020 (excluding marginal fuelwood used in rural areas) - AME demand scenario, Stable 2009 plantations and High productivity
dem20_ame_4km	= focalmean(dem20_ame, circle, 40) 2 times
pcful20m_am4k	Percent fulfilled within a 4km context - Demand 2020 AME & High productivity = avmai_m_4km / dem20ame_4km * 100
dem20m_amf70c	Adjustment factor reducing the consumption of "conventional" fuelwood in rural areas on account of scarce resources (max reduction to 70% of demand) - 2020 AME demand & High productivity variant. = model "from percent fulfilled to 2020demand ame_man factor"
dem20adjmam70	**Demand 2020 revised - AME demand 2020 & High productivity variant.** = ("%dem20_ame%" * "%dem20m_amf70c%") / 100

Supply Module		
		Supply 2009
For29sep	v	Harmonized forest map (version 29 Sep 2012) contained in geodatabase **forest29sep2012.mdb**
for29sep12	r	Forest map with unicode for formation, species and density
plant_1		mask of plantations Con("for_uni_land" < 20000000,Con("for_uni_land" > 10000000,1),0)
for_prov_uniq	r	Raster map of forests with unique numeric code
for_uni_land	r	Unicode
uni_lc_rain	r	Unicode map dividing non-forest land into rainfall classes, necessary to distribute ToF resources.
nofor_msk		Non forest mask (value=1) (including protected areas)
ac_uni_lc_r	r	Unicode map dividing non-forest land into rainfall classes excluding non-accessible areas (value 0, like water)
ac_nofor_msk		Legally accessible Non forest mask (value=1; protected non-forest=0) = "%nofor_msk%" * "%leg_acc%"
mai_kg_bau		Mean Annual Increment - Low productivity variant (od kg/pixel)
mai_kg_man		Mean Annual Increment - High productivity variant (od kg/pixel)
acmai_bau		Accessible MAI - Low productivity variant (od kg/pixel)
acmai_man		Accessible MAI - High productivity variant (od kg/pixel)
av_factor_bau		Reduction facto to deduct industrial sawnwood from supply potential - Low productivity variant
av_factor_man		Reduction facto to deduct industrial sawnwood from supply potential - High productivity variant
avmai_bau		Available MAI after deduction of sawnwood demand - BAU variant (od kg/pixel)
avmai_man		Available MAI after deduction of sawnwood demand - MAN variant (od kg/pixel) = "%acmai_man%" * "%av_factor_man%" / 1000
avmai_x		Available MAI after deduction of sawnwood demand - Medium variant (od kg/pixel) = ("avmai_bau" + "avmai_man") / 2
		Supply 2020
mul_pl_110		Multiplier map to increase plantation productivity by 10%
avmai20b_plan		Available plantation productivity 2020 - Low productivity variant (odkg / pixel)
avmai20x_plan		Available plantation productivity 2020 - Medium productivity variant (odkg / pixel)
avmai20m_plan		Available plantation productivity 2020 - High productivity variant (odkg / pixel)
avmai20_b		Available total productivity 2020 - Low productivity variant (odkg / pixel)
avmai20_x		Available total productivity 2020 - Medium productivity variant (odkg / pixel)
avmai20_m		Available total productivity 2020 - High productivity variant (odkg / pixel)
		ToF - wood resources outside CGIS Forest Map (below 0.25 ha)
tof_out_for2tmp.mdb		Geodatabase with results of the TOF survey carried out in 2009 (WISDOM 2009) reviewed by removing all plantation polygons that are now in the new CGIS forest map. The results are analyzed by rainfall zone in **tof2_pivot.xls**
Integration Module		
bal_bau_09	r	Pixel-level balance Low productivity variant
bal_man_09		Pixel-level balance High productivity variant
bal_bau09_2km		Local balance Low productivity variant

bal_man09_2km	Local balance High productivity variant
bal_x09_2km	Local balance Medium productivity variant (Average of two above)
	balance maps based on revised demand maps
	Balance 2009
	Pixel-level balance
bal09_x_x70	Local balance Medium productivity variant & adjusted Med. prod demand "%avmai_x%" - "%dem09_adj_x70%"
bal9_b_b7_2km	Local balance Low productivity variant & adjusted low prod demand = "%avmai_bau%" - "%dem09_adj_b70%"
bal9_m_m7_2km	Local balance High productivity variant & adjusted high prod demand = "%avmai_man%" - "%dem09_adj_m70%"
bal9_x_x7_2km	Local balance Medium productivity variant & adjusted demand = Average of two above: ("%bal9_b_b7_2km%" + "%bal9_m_m7_2km%") / 2
	Balance 2020
bal20_x_bx7	Balance for 2020 assuming Medium productivity (**avmai20_x**) and BAU demand adjusted to Medium productivity 2020. = **avmai20_**x - dem20adjx_b70
bal20_x_amx7	Balance for 2020 assuming Medium productivity (**avmai20_x**) and AME demand adjusted to Medium productivity 2020. = **avmai20_**x - dem20adjxam70
bal20x_x7_2km	Local balance (smoothed on 2km context) for 2020 assuming Medium productivity (**avmai20_x**) and BAU demand adjusted to Medium productivity 2020. = **focalmean of bal20_x_bx7**

ANNEX 7: TERMS OF REFERENCE

1. Context

The Support Project for Reforestation, PAREF[2], is in line with the implementation of the National Forest Policy and Rwanda Economic Development and Poverty Reduction Strategy. The Programme contributes to the reinforcement of the capacities of the National Forestry Authority (NAFA). For this reason, the Project must (i) develop tools to assist decision-making such as masters plans for the supply of cities and towns in wood combustibles (SDA in French acronym) and an information system for permanent evaluation (SIEP in French acronym) and (ii) contribute to the reinforcement of the forest management framework, particularly through the updating and popularisation of the Forest Law and the restructuring of the National Forest Fund (NFF).

Specifically, it aims for the development or reconversion of 10,000 ha of public forests for the production of wood energy in order to contribute to approximately 8% of domestic demand in charcoal, and approximately 3% of domestic demand in fuelwood.

The Project contributes to the following overall objective: **"The implementation of the national forest policy contributes to the poverty reduction, economic growth and environmental protection"**

The Project pursues the following specific objective:

«Quantitative and qualitative degradation of forestry resources is under control and Rwandan needs in wood fuel are better assured»

PAREF consists of two components as follows:

- PAREF Be : Afforestation Support Program in 6 Districts (Northern Province : Gakenke, Gicumbi and Rulindo; Eastern Province: Bugesera, Kirehe and Ngoma)

and

- PAREF PB : Afforestation Support Program of 9 Districts (Northern Province : Burera and Musanze; Western Province: Karongi, Ngororero, Nyabihu, Nyamasheke, Rubavu, Rusizi and Rutsiro).

PAREF Be aims at achieving the following results:

- Institutional capacities of the forestry sector are reinforced at all levels of intervention;
- 10.000 ha of forestry settlements in the 6 selected Districts (3 in Northern Province and 3 in Eastern Province) are developed and managed for sustainable supply of wood and the afforestation needs for more than 2.000 ha are met;
- Energy saving activities value is increased.

While PAREF II seeks to achieve the following intermediate results:

- Institutional capacities at the decentralized level are reinforced in the field of reforestation and forestry resources management.
- Forestry resources - afforestation of 10,000 ha created and/or rehabilitated in the 9 selected Districts (7 in the Western Province and 2 in the Northern Province) - are increased and the required mechanisms to their rational management are put in place.
- Valorisation of wood energy is improved.

Key activities of PAREF include the following:

- To reinforce institutional capacities (MINIFOM, NAFA, Districts partners);
- To reinforce the operational capacities of various public and private actors within framework of the decentralized management of the forestry resources and support the introduction and dissemination of new technologies of efficient use of wood energy;
- To improve the wood energy valorization through improvement of carbonization techniques, introduction of improved stoves and marketing of forestry products in particular through professionalization of actors in the wood energy sector and introduction of an incentive tax system;
- To increase productive forestry resources of 15 selected Districts and set up necessary mechanisms to their sustainable management with a perspective of income generation for the public and private operators: afforestation of new areas, rehabilitation and/or reconversion of existing forests, promotion of agroforestry;
- To make jobs in the forest sector attractive by creating and restructuring organizations of Forestry Management Groups (FMG).

2. Justification

More than 95% of energy consumption at household's level comes from fuelwood and charcoal in rural areas while charcoal accounts for at least 90% of energy consumption at urban household's level. There is considerable pressure on natural resources, especially forests. Therefore, the Government of Rwanda through MINIFOM and other stakeholders, aims at acquiring appropriate planning instruments conducive to sustainable forest management. The fuelwood and charcoal supply master plan is such an instrument.

There is a need to assess the demand and consumption of fuelwood and charcoal in urban areas on one hand and on the other hand there is a need to assess the supply capacity of forests located around Kigali. Indeed, both Rwandan urban and rural population heavily rely on fuelwood and charcoal for meeting household energy needs. Woody biomass is a source of renewable energy in Rwanda and the country's energy policy is to promote modern (more efficient) energy use. Although, this is conditioned by sustainable management of national biomass resources. Meanwhile, population is growing whereas forest area is, at best, stagnating.

The collapse of the balance between supply of and demand for fuelwood and charcoal could result in a precarious situation for the entire country, hampering economic development. Insufficient fuelwood and charcoal supply will lead to fast growing fossil energy imports, hence a higher need for hard currency with negative impacts on economic indicators.

Vision 2020 states that the forestry sector has to become one of the main pillars of Rwanda's rural economy. The current program of MINIFOM aims to plant around 80.000 ha/year during the next 3 years (2011-2013) in order to reach a national forest cover of 30%.

The prominent role of a tool such as the Supply Master Plan for fuelwood and charcoal in urban areas within the decision-making platform will contribute to boosting and enhancing the forestry business in Rwanda.

A specialized system for examining wood energy issues has already been used to assess Rwanda's needs and supply constraints in the framework of the Project "Rationalisation de la filière bois- énergie", (Rationalization of wood energy) FAO/TCP/RWA/3103.

This system called "Woodfuel Integrated Supply/Demand Overview Mapping" (WISDOM) provides the first geo-referenced vision of the country's productive potential, woodfuel consumption and supply/demand balance under current conditions as well as under alternative scenarios, serving as basis for the formulation of locally-tailored wood energy strategies[3].

In order to achieve sustainable wood energy systems the study recommended to:

- Orient the remedial action in all possible direction (management, efficiency, new planting areas, promotion of affordable fuel alternatives, etc.) through strong institutional synergies and with clear territorial priorities.
- Tailor the character and emphasis of the actions to locally varying supply/demand situations.
- Share WISDOM for evaluation, update and, most important, use, with all concerned institutions.
- Provide MINIFOM/NAFA with appropriate technical and financial support to develop the technical capacities required for maintenance and full exploitation of WISDOM Rwanda.
- Strengthen the WISDOM dataset with improved information for the following aspects:
    - Detailed and up-to-date forest cover (≥ 0,25 ha) on the basis of the high resolution aerial photos produced by the National Land Centre (this issue is ongoing through C-GIS);
    - Assess the contribution of "trees outside forests" (< 0,25ha) to the woody biomass in rural areas (on the same basis);
    - Reliable data on the sustainable productive capacities of plantations, tree and shrub in farm areas as well as residues from agricultural crops;
    - Precise data on rural consumption patterns by households and non-households, specifically on the amounts and the specific mix of fuelwood and farm residues;
    - Reliable information on wood-processing industries (sawmills and furniture making) and on woodfuel-consuming industries (brick-making, etc.).
- Join institutional resources and multilateral/bilateral development aid in order to upgrade the WISDOM knowledge base with data adequate to high intensity planning.

3. Objectives

The main objective of the present mission is to provide a decision making tool for planning and monitoring districts forest resources management for a sustainable supply of woodfuel of Kigali.

Specific objectives of this mission are as follows:

- Enhance the WISDOM with the view of using spatial (cartographic) information for the sustainable management of forest resources.
- Compare the supply and the demand of Kigali for fuelwood and charcoal at present and outline forecasts over the next ten years in line with vision 2020.
- Assess the pros and cons as well as implementation technicalities of levying taxes on fuelwood and charcoal businesses without conflicting with sustainable forest management principles.

4. Expected Results

The following key results shall be expected upon completion of the mission:

- A fuelwood and charcoal Supply Master Plan for Kigali. The document of no more than 30 pages shall address the supply and demand terms of charcoal and fuelwood used in Kigali; all relevant figures, tables and maps shall be given in appendices to the report (i.e. for the supply area of Kigali precise by district: the fuelwood and timber volume and annual production, flows of woodfuel and charcoal for Kigali, demographic trends in the supply area of Kigali, production & exploitation.

- The consultant shall design and prepare a database linked with a GIS, based on the WISDOM methodology and compatible with ArcGIS and MsAccess, where information relevant to Urban Supply Master Plan for Fuelwood and Charcoal shall be retrieved. The GIS shall be compatible with the WISDOM system and integrate the information collected by the WISDOM Rwanda. The conceived GIS and DBMS shall be designed to integrate future data of the national forestry inventory planned by PAREF Be II, as well as to be updated with the new detailed forest mapping.

- Future users of the database shall be trained on the task during the mission, in particular how to capture data, maintain database and, where necessary, to improve and adapt its layout (data entry page, table of attribute, queries, reporting features, etc.).

- The consultant shall hand over three soft copies of the SMP with the database and the GIS on DVD-ROM as well as the source code of the database. The package will include a « read me first » file where installation and utilisation guidelines for the GIS and DBMS can be consulted (in particular how to complete and update the DBMS/GIS and the SMP once the new forest mapping and inventory are completed). The DVD shall contain also the raw data collected through the surveys as well as all analysis done together with all used and/or produced shape-files with their attributes.

- Findings shall be presented, during a one-day workshop held in Kigali, to PAREF, MINIFOM Representatives as well as other stakeholders involved with decentralization and economic development. During this workshop, the Team Leader shall submit his/her draft report and present a PowerPoint to provide the workshop participants with surveys results as well as strategic guidelines. The Team Leader will focus on the value added by the fuelwood and charcoal Supply Master Plan. He/she will outline an implementation plan for the SMP accordingly.

- The fuelwood and charcoal Supply Master Plan shall be written in French or English. It will include an executive summary of not more than 2 pages, written in French AND English.

5. Methodology and Activities

Regarding the elaboration of the fuelwood and charcoal Supply Master Plan, the team of consultants has to analyse first of all the tools implemented at NAFA by the WISDOM Rwanda project in order to improve and complete, detail and update the cartographic and database information. The team will have to review secondary data and previous studies. They will conduct interviews with key informants and stakeholders in various institutions (NAFA, MINIFOM, MINALOC, NUR, etc.) and shall address various topics through a variety of surveys as:

- Assessment of household energy consumption patterns and trends of consumption patterns; hard data shall be collected for fuelwood and charcoal utilization only. Other sources of domestic energy shall be described on the basis of a critical review and analyses of secondary data and previous studies (see references hereafter). This analysis shall address the share of domestic energy, in particular woodfuel, in household expenditure.

- Survey and analysis of fuelwood and charcoal market conditions including pricing, supply patterns, taxation schemes, retail outlets, profiles of traders and business models involved in fuelwood and charcoal trading activities.

- Assessment of fuelwood and charcoal supply patterns centred on Kigali. Based on previous studies, up-to-date forest cover maps, the team of consultants will provide a synthesis of fuelwood and charcoal volumes (those estimations will be updated with the results of the national inventory planned in 2011). The rationale behind this investigation is to contrast current levels of wood harvest with natural increments, i.e. in accordance with sustainable forest management principles. In addition, a forecast analysis shall be performed in order to contrast trends in demand with future supply levels. A GIS-based approach shall be envisaged since fuelwood and charcoal suppliers are supposedly (but not confirmed) located around urban areas according to a more or less concentric pattern.

- Technical and financial analyses of local management of natural resources, i.e. how local actors manage forest stands for producing fuelwood and charcoal. The team of consultants will investigate socio-economic dimensions of fuelwood and charcoal production schemes, for example number of jobs created by these activities, range of monetary compensation, health, safety and environmental issues. It is of critical importance to gauge the economic magnitude of fuelwood and charcoal trading activities for the main urban areas in Rwanda. These analyses will cover the entire value chain, i.e. from stump to household cooking oven including planning, exploitation, carbonization, transport, storage, retail, etc.

- Opportunities and threats regarding taxation strategy shall be addressed too. In addition, trading and retailing organization shall be critically reviewed. How to enforce tax and levies on fuelwood and charcoal without jeopardizing sustainable forest management?

In short, they will coordinate and supervise the field investigations mentioned below. The consultants shall also make sure that during the mission adequate on-the-job training is provided and local capacity is built up accordingly.

It is noteworthy to mention the following:

- Opportunities and threats regarding taxation strategy shall be addressed.

- Data collection at household level: this survey should provide up-to-date figures on consumption patterns in urban areas. Samples shall be adequate in terms of size and location. They may amount to several hundred households in total.

- Data collection at selected road check points: a few roads give access to Kigali City. Lorries and other vehicles carrying fuelwood and charcoal can be accounted for and loads can be assessed over an appropriate period of time. Here again, samples shall be determined to offer reliable estimates.

- Other field surveys will address socio-economic and financial topics related to the value chain for fuelwood and charcoal production and trade.

- The bidder will propose a methodology tailored to Rwandan conditions and forest management needs. The proposed methodology will not exceed 20 pages and will emphasized conceptual choices and statistical analyses. It shall also address on-the-job training and capacity building issues at different appropriate levels as a matter to sustain the work beyond the short-term assignment carried out by the consultants. An user guide for the DBMS and GIS should also be elaborated separately.

6. Resource Requirement

The following resources will be necessary.

- Relevant maps and data on forest stands as far as they are available, shall be provided by NAFA, PAREF or other entities (C-GIS) to the team of consultants.
- The database and the maps of WISDOM Rwanda as well as secondary data and previous studies shall be made available to the team of consultant since the very beginning of the mission.
- GIS and DBMS software necessary to perform the mission shall be provided by the consultant and handed over to NAFA / PAREF at the end of the mission.
- Local surveyors shall be recruited by the consultants. Transport means will be organised by the consultants.

7. Expert Profile

A team of three consultants shall be in charge of the study. The consultants will be assisted by local surveyors and field agents.

7.1 International Expert in woodfuel and domestic energy thematic in Africa / Team Leader

He/she shall be responsible for the following tasks:

- Meet with various stakeholders and key informants.
- Design - in consultation with the expert in socio-economy - relevant questionnaires and semi- structured interviews.
- Coordinate, facilitate and supervise field surveys and data collection.
- Set-up the DBMS and GIS in consultation with PAREF and NAFA, based on the WISDOM methodology.
- Supervise data retrieval.
- Process data including the production of thematic layers, statistical analyses and relevant charts describing fuelwood and charcoal production and utilization patterns.
- Carry out technical and financial analyses about the fuelwood and charcoal production and trade value chain.

- Supervise the on-the-job training and local capacity building in the course of the mission. Hand-over GIS and DBMS related to SMP for the urban area of Kigali. Compile SMP report (max 30 pages) for Kigali.
- Organise a final workshop to present the draft report and explain the key features of the fuelwood and charcoal supply master plan.

Profile

The International Expert in woodfuel and domestic energy thematic in Africa / Team Leader will have the following profile:

- Over 15 years of professional experience including more than 5 years as team leader.
- Master degree in forestry sciences or relevant disciplines.
- Expert knowledge in GIS, DBMS and GPS software and hardware.
- Experience in fuelwood and charcoal supply thematic in urban areas in Africa. A previous
- experience in Rwanda or in the subregion will be considered as an asset.
- Excellent drafting, analytical, communication, coordination and inter-personnel skills. Excellent command of English and French language.
- Ability to pursue high standards of work and to be organized and effective. Ability to coordinate work effectively in a multi-disciplinary team.

7.2 Local Forestry Expert

He/she shall be responsible for the following tasks:

- Review secondary data and relevant documentation.
- Assist the Team Leader in identifying the survey locations.
- Train field surveyors according to a data collection protocol.
- Coordinate field surveys in accordance with instructions given by the Team Leader. Assist the Team Leader in data retrieving and processing. Assist the team leader in compiling reports.
- Contribute to training local experts and strengthen local capacity in specific expertise.

Profile

The local forestry expert will have the following profile:

- University degree (A0) in forestry sciences with at least 5 years of professional experience.
- Previous experience in field surveys.
- Good knowledge of data retrieval and processing, spreadsheet or database management; a good knowledge of GIS will be an asset.
- Acquainted with measuring instruments and statistical analysis. Native speaker of Kinyarwanda.
- Excellent command of English or French language.
- Ability to pursue high standards of work and to be organized and effective. To be communicative and teamwork oriented.

7.3 Regional or Local Expert in socio-economics

He/she shall be responsible for the following tasks:

- Assist the Team Leader in all tasks relevant to the mission.
- Facilitate contacts with key stakeholders and informants.
- Design and test relevant questionnaires and semi-structured interviews (SSI). Select and train surveyors in using questionnaires and SSI.
- Contribute to the training of national technicians and strengthen local capacity in specific expertise.
- Supervise, coordinate and facilitate field surveys and data collection.
- Perform data and information quality control through cross-verification. Carry-out socio-economic analysis.
- Assist the team leader in compiling the SMP report.

Profile

The regional socio-economist will have the following profile:

- A university degree (A0) in social sciences, socio-economy or economics or equivalent discipline.
- Over 7 years of professional experience in Africa.
- In-depth knowledge of the rural sector in Rwanda will be an asset.
- Well acquainted with data processing software and statistical analysis.
- Expert knowledge in domestic energy issues in both rural and urban areas.
- Previous experience in fuelwood and charcoal supply thematic in urban areas in Africa.
- Excellent drafting, analytical, communication, coordination and inter-personnel skills. Good knowledge of Kinyarwanda.
- Excellent command of English or French language.
- Ability to pursue high standards of work and to be organized and effective. Ability to work effectively in a multi-disciplinary team. To be communicative and teamwork oriented.

8. Duration of the mission

10 weeks

9. Location of the mission

Kigali and the whole territory of Rwanda

10. Useful References

- C-GIS/NUR [2007-2011] - Cartographie des Forêts du Rwanda 2007 (actualisation détaillée en 2011 sur base des ortho-photos aériennes de NLC)
- Drigo R., Nzabanita V. [2011] - WISDOM Rwanda, Spatial analysis of woodfuel production and consumption in Rwanda applying the Woodfuel Integrated Supply/Demand Overview Mapping methodology (WISDOM), FAO, Roma
- ISAR [2008] - Inventaire des Ressources Ligneuses du Rwanda, Rapport final, Rwanda, Kigali
- MININFRA [2009] - Biomass Energy Strategy (BEST)
- MININFRA [2009] - Rwanda biomass energy & stoves survey report (prepared by Green & Clean Solutions Ltd)
- NAFA/PAREF, Ministère des Forêts et des Mines [2010] - Espèces ligneuses recommandées dans les opérations de reboisements et d'agroforesterie par zone agro-bioclimatique du Rwanda Kigali, 205 p.
- Tossero, M. A., Gauthier M., Drigo R., Salbitano F. [2008] - WISDOM for cities; Analysis of wood energy and urbanization using WISDOM methodology, FAO, Roma

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The following section contains relevant parts as taken from Technical proposal prepared by Agriconsulting S.p.A. Section TECH-4 . Description of the Approach, Methodology and Work Plan for Performing the Assignment.

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1.2.3 Understanding the Supply Masterplan

1.2.3.1 Masterplan description: objectives and outputs

As stated in the Terms of Reference, “the prominent role of a tool such as the Supply Master Plan for fuelwood and charcoal in urban areas within the decision-making platform will contribute to boosting and enhancing the forestry business in Rwanda”.

The scope of the SMP (through the underlying Enhanced WISDOM Rwanda) will be to support decision-making for MINIFOM’s forestry program in the framework of Vision 2020. Concerning the important plantation program (80,000 ha/year in the next three years), the detailed geo-referenced database will contribute to optimize the planting scheme in consideration of slope conditions, current land uses, site suitability, land tenure and other factors.

Given the difficulty in matching the demand for woodfuels with sustainable production that characterize the country as a whole[33], the Supply Master Plan for Kigali will necessarily be the result of nation-wide analysis. The demand for woodfuels of Kigali must be added to the demand of all other urban centres since they all compete for the same limited resources. Kigali’s woodfuel market is the most important one but it’s not the only one. Either the supply of woodfuel can be made sustainable for all urban markets or for none.

In this context, the scope of the WISDOM analysis will be that of assessing as accurately as possible the present situation and to support the identification of the most appropriate “blend” of measures aiming at a sustainable wood energy system for Kigali as well as for the rest of the country, in line with Vision 2020. The fundamental questions are to: quantify and locate current wood resources; quantify and locate current

[33] According to FAO-NAFA/WISDOM and MININFRA/BEST analyses.

and future demand; quantify and locate the new plantation areas (according to slope, current land use, site suitability, etc.); quantify and locate the target areas for forest management and rehabilitation programs; quantify and locate revenue and job generation; quantify and locate priority areas for agroforestry programs; quantify and locate the priority areas for improved stoves dissemination programs; quantify and locate priority areas for alternative fuel promotion programs; etc..

The limitations posed by each component will determine the target of the next one, in a cumulative progressive process: The limit of the current sustainable productivity will set the target for management/rehabilitation programs; whose limits will set the target for new plantation areas; whose limits (maximum suitable area and productivity) will set the target for agroforestry programs; whose limits will set the target for demand reduction programs; etc...

Alternative scenarios will be developed, including the "business-as-usual" that represent the present situation and realistic "blends" of improved forest management, increased plantation areas, increased conversion efficiencies, alternative fuel promotion programmes that can be realistically achieved by 2020.

The regulatory framework, including cutting permits and taxation policy will be defined with the objective of achieving the targets defined by the WISDOM analysis.

The WISDOM analysis and the regulatory framework will form the basis of the Supply Master Plan.

1.2.3.2 Key Issues and Constraints

Several important parameters that will be used in the analysis (the productivity of forest plantations, the effectiveness of management and plantation programs, the penetration of alternative fuels, etc.) will be reviewed in course of time as more reliable information will become available (most notably, the results of the forthcoming forest inventory). In this sense the Master Plan prepared will be the first version, which will require periodic revision/update on the basis of new available evidence.

< ... >

ANNEX 8: MINUTES OF THE VALIDATION WORKSHOP

MINISTRY OF NATURAL RESOURCES – MINIRENA
Rwanda Natural Resources Authority, RNRA
DFNC - BP 433 Kigali

BTC RWANDA

PAREF Be2

Support Program to the Development of the Forestry Sector

Workshop minutes

Date: 17/07/2013	**Venue:** Woodland Hotel, Kimironko, Kigali

Meeting participants:

38 stakeholders of the forestry and energy sectors, see Annex 1: List of participants

Aim: Discussion on and validation of the study carried out by Agriconsulting on the elaboration of a Supply Master Plan for firewood and charcoal of Kigali City

Workshop program :

8h – 8h30	Registration
8h30- 8h45	Opening note (RNRA representative)
8h45 – 10h00	Main results of WISDOM update (2009 and 2020 scenarios) and Value Chain analysis (Drigo, Agriconsulting)
10h00 – 10h30	Coffee/tea break
10h30 – 11h30	Main recommendations and basis for the Supply Master Plan of Kigali (Drigo,
11h30 – 13h30	Agriconsulting)
13h30 – 14h00	Discussion, comments and recommendations for validation - chaired by DDG/DI
14h00 – 15h30	Closing remarks and validation – DDG
	Lunch and Afternoon Workshop session

Main conclusions

1. The workshop was opened by the DDG of the Department of Forestry and Nature Conservation, highlighting the importance of wood for simple daily life activities such as cooking. There is a need to acknowledge this importance and invest in forests and forestry, in order to raise wood production. An increase in wood production has an important potential to improve the lives of the poorest.

   Words of thanks were expressed to those who made the study possible.

2. In the first session, R. Drigo of Agriconsulting presented the main results of the WISDOM update, explaining in detail the parameters and figures used in the different scenarios considered and the data sources consulted. It was not considered sufficient to study the balance between supply and demand of wood in Kigali only, since this balance would certainly turn out to be negative. Data from the entire Rwandan territory were needed to be able to make recommendations and propose adequate solutions.

   The analysis shows that currently in Rwanda a gap of 870 kilo tons of wood per year (in oven dry

	wood equivalents) exists, and this gap is expected to increase to 2110 kilo tonnes per year by 2020 if no corrective actions are taken. The main recommendations as regards further data needs and appropriation of the WISDOM tool by DFNC were highlighted. Furthermore, the market values of charcoal and fuelwood, the distribution of income over the value chain and the jobs created by the charcoal and fuelwood markets were discussed. During the second presentation session, emphasis was put on strategic recommendations, on how to move on based on the results of the study, without compromising the people's needs nor the quality of the environment. Supply and demand zones of firewood and charcoal were identified, and possible interventions for filling the gap of 2.1 million tons of wood by 2020 discussed. The interventions should be tailored to the local conditions of each Province/District. Examples were provided on how to set objectives at Province, District and Sector level. A link to all slides, the current draft and the final document will be sent to all participants by e-mail.
3.	Is the probable increase in electricity use on the countryside considered in the forecasted wood demand? → electricity is included under the category 'other fuels'. However, it is believed that, at least in the short term (up to 2020), electricity will not be able to replace wood or charcoal as cooking fuel. Only gas is considered to be a real potential substitute. In the forecasts, the combined impact of an increase in the use of electricity, biogas and peat on the reduction of the gap remains limited to less than 1% of the gap.
4.	The potential impact of export of wood to neighboring countries has been studied, but very little data were available. It was found that wood export mainly takes place by 'on head' transport, large trucks are not involved. Therefore, quantities were considered negligible for the aims of this study.
5.	'Trees outside forests' are classified as such based on the resolution of the forest cover map: all trees found in wooded areas under 0,25 ha are considered to be 'Trees outside Forests'.
6.	The data on the profits generated per part of the charcoal chain are the results of thorough analyses, no opinions are expressed. Data were checked and rechecked, since the results were a little unexpected. It is commonly accepted that the main profit is generated by the distribution part of the value chain, but this study points out that most profits are generated in the production part. These results should perhaps be verified by a more detailed and comprehensive study on the value chain.
7.	This study is the result of an assignment of 14 weeks. Stakeholders such as charcoal makers, market traders and households were involved in the elaboration of the study through interviews and surveys. The study itself is an analysis only, it provides suggestions for further research and a strategy to solve the issues (gaps) identified. Support for implementation of this strategy is not part of the assignment, the implementation itself is rather a task of the decision makers involved. They should translate the proposed strategy into an action plan, specifying deadlines and persons/institutions responsible for carrying out the activities identified.
8.	The report clearly covers more than only an analysis at the level of Kigali City. It is a national-level assessment, including a strategy covering the entire Rwandan territory. Therefore, it would be good to change the title, which currently suggests a strong focus on Kigali.

9. Information on the type of plantation/land (public or private) supplying the wood is currently not available (work on a cadaster is still ongoing), and could therefore not be included in the analysis.
10. It should be noticed that the promotion of agroforestry could conflict with the Land Consolidation efforts, which tend to promote an increase in surface area of agricultural exploitations, to improve their productivity. However, even with this potential conflict in mind, the 2 % increase in tree cover in agroforestry systems, recommended by the present study, is considered an achievable objective.
11. It was suggested that people should be encouraged to use firewood rather than charcoal, since this improves the energy efficiency of the entire burning process. Improved stoves exist which convert firewood into charcoal and recover the energy. However, promoting the use of firewood in general is not feasible, since certainly in cities, apart from the energy efficiency, other parameters such as the indoor air quality come into play. On the countryside it would be possible. The current report does not include this recommendation as such, but rather recommends the use of improved stoves in general, whether they use firewood or charcoal as a fuel. A wide range of improved stoves exists. A separate, in depth study should determine what kind of improved stoves should be promoted and where.
12. The price of wood is very low, and probably does not always cover the full cost of sustainable production. It was therefore suggested to add a recommendation on encouraging landowners to organize themselves in cooperatives, so that they have a better idea of the costs involved and the true price of their product, and do not sell it uninformed. This could lead to a more sustainable production but at the same time of course also to higher market prices for wood and charcoal.
13. It was recommended that an additional study be conducted on a supply master plan for timber.
14. A study on the use of agricultural residues as fuel , among others to follow up on what would happen if the wood deficit increases, would be welcomed. This recommendation is already included in the report.
15. The present report gives recommendations with regard to the harmonization of taxes and criteria for cutting permits, since it was observed that these aspects vary widely between Districts. In some places this leads to among others clandestine and bad charcoal making practices . The basic tax requirements are the same in each District, but the additional taxes charged differ. In se, there is no issue in having different taxation systems per District, if these systems are adapted to the specific needs of the Districts and to a general vision on forest management/ wood use objectives (e.g. does the District want to favor charcoal making or not?). More specific recommendations for Districts/regions regarding taxation issues can only be provided once the new forest law and the new District forest management plans etc. become available.
16. The current study is a working document, it should be updated when new data become available, as many times as needed.
17. The report as a whole was approved by the audience. Some recommendations made during this workshop should be added, but there is no need for any new analyses or data collection to be done. The title should be changed, so that it is clear that the study covers all of Rwanda.

Actions planned		
Action	**Responsable**	**Timing**
Add the extra recommendations made (see minutes) to the list of recommendations of the final draft document, and change the title of the report to: "Update and upgrade of WISDOM Rwanda and Woodfuels value chain analysis - as a basis for the Rwanda Supply Master Plan for fuelwood and charcoal".	Agriconsulting	31/07
Publish and distribute the final document	DFNC	31/08

Signatures		
Institution - function	**Name**	**Signature**
DFNC, DDG	Mukashema Adrie	
PAREF Be2, Director of Intervention	Mutuyeyezu Alphonse	